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NAVPERS 93584

TEST EQUIPMENT

TRAINEE'S GUIDE
for
FIRE CONTROL TECHNICIAN TRAINING

STANFORD UNIVERSITY
MAR 1967
DOCUMENT DIVISION

DECEMBER 1966

BUREAU OF NAVAL PERSONNEL

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

DEPARTMENT OF THE NAVY
BUREAU OF NAVAL PERSONNEL
WASHINGTON, D.C. 20370

2 September 1966

TEST EQUIPMENT
TRAINEE'S GUIDE
NAVPERS 93584

1. This publication and the companion Instructor's Guide, NAVPERS 93583 are the approved curriculum for Test Equipment block of instruction in Navy Fire Control Technicians Schools, Class "A" and are effective upon receipt.

2. Corrections and recommended changes to this publication are invited. Commanding Officer, Service School Command, U. S. Naval Training Center, Great Lakes, Illinois 60088, has been assigned clearing house responsibility for evaluating and compiling recommended improvements, and for submitting them to the Chief of Naval Personnel in the form of a proposed change to the publication. Users of this course material are requested to submit their recommendations directly to the command having clearing house responsibility, with a copy to the Chief of Naval Personnel (Attn: Pers-C12). No deviations from this curriculum are authorized until approved by the Chief of Naval Personnel.

3. This publication supersedes Fire Control Radar Special Circuits, NAVPERS 92213A, Volume 2.

J W Perkins

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SAFETY NOTICE

WARNING

The attention of all hands is directed to Section V, Chapter 67 of Bureau of Ships Technical Manual or superseding instructions on the subject of safety.

Dangerous voltages are employed in the training devices and equipments used throughout this course. Contact with live circuits can result in permanent injury or death.

NEVER MEASURE POTENTIALS OVER 600 VOLTS BY MEANS OF FLEXIBLE TEST LEADS OR PROBES.

DON'T SERVICE OR ADJUST ALONE:

Under no circumstances should any person work on live equipment without the immediate presence or assistance of another person capable of rendering aid.

DON'T TAMPER WITH INTERLOCKS

NOTES

(A) MAKE SURE you are NOT GROUNDED whenever working near or using test equipment on live circuits.
(B) In general, USE ONE HAND only when working around live circuits.
(C) ALWAYS ground the metal case of test equipment before using.
(D) NO NOT FORGET that high voltages MAY BE PRESENT across terminals that are normally low voltage due to component breakdown or equipment malfunction. Use care even when measuring low voltages.
(E) NEVER USE electrical or electronic equipment known to be in poor condition.
(F) ALWAYS inspect test leads, line cords, etc., to insure that no cracked or broken insulation, frayed wires or loose connections exist, before using any portable electrical or electronic equipment.
(G) High-voltage, high-capacity capacitors should be discharged with a suitably insulated shorting or grounding bar with about 10 ohms in series with the grounded line. Where neither terminal of a capacitor is grounded, short the terminals to each other.

RESUSCITATION

Approved posters illustrating the correct procedures and listing rules for resuscitation must be displayed prominently in each fire control, radio, radar, or sonar enclosure. These posters may be obtained upon request to the Bureau of Medicine and Surgery. Formerly, manual methods of artificial respiration were used exclusively. These methods include the prone pressure method, the hip lift-back pressure method, the arm lift-chest pressure method, the arm lift-back pressure method, and Eve's method (rocking on a stretcher). More recently, the "rescue breathing" methods have come into prominent use. These latter methods represent the most efficient means of resuscitation without the use of special equipment, and include mouth-to-mouth, mouth-to-nose, and mouth-to-mouth-and-nose techniques.

Mouth-to-mouth resuscitation is accomplished by sealing one's mouth over the patient's mouth, pinching the nostrils shut, and blowing until his chest lifts—an indication that his lungs are filled with air. The air is then allowed to escape, and the procedure is repeated at the normal rate of breathing until the patient can breathe for himself.

Resuscitation using the patient's nose for an airway is as satisfactory as the mouth-to-mouth method. It is the method preferred by many. When this method is used, the patient's mouth is held closed as air is blown into the nose.

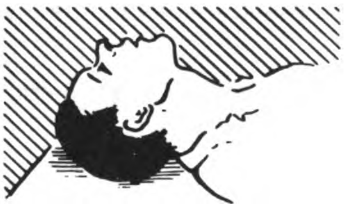
Both the nose and mouth may be used as the patient's airway. This method is, in fact, quite often used when administering resuscitation to infants.

SUMMARY OF STEPS USED IN RESCUE BREATHING:

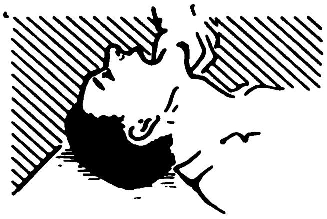
1. Start the process immediately.
2. Place the patient on his back.
3. Clear the mouth and throat of debris.
4. Tilt the patient's head back.
5. Pull the patient's chin forward, using the middle fingers, so that the lower jaw is literally lifted and it "juts out". This step is necessary to keep the tongue out of the air passage. The lifting is accomplished by placing fingers beneath the jawbone and behind it on a line almost perpendicular to the ear. Using one hand, hold the jaw in this position.
6. Blow air through mouth or nose (or both) until chest rises. (Nostrils should be pinched with fingers if mouth-to-mouth method is used.)
7. Remove your mouth and listen for snoring and gurgling—signs of throat obstruction. If the throat is obstructed, turn the patient quickly on his side and administer several blows between the shoulder blades in an effort to dislodge the obstruction.
8. The complete cycle of filling the patient's lungs with air and allowing them to deflate should be smooth, with each complete cycle starting at approximately five-second intervals.
9. Continue rescue breathing until the patient breathes for himself.

Although rescue breathing is the preferred method for administering artificial respiration, the technician should be skilled in other methods in order to manage situations where rescue breathing cannot be used. The method to be used is dictated by the condition of the patient, the availability of equipment and trained personnel, and the particular environment.

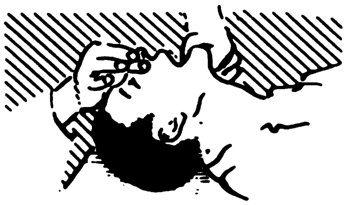
There are procedures applicable to all methods of resuscitation. The first thing is to begin immediately by putting the patient in the proper position. DO NOT WAIT FOR HELP OR EQUIPMENT. Since every second counts, start the resuscitation and attend to secondary measures as you proceed. The important thing is to establish and maintain the rhythm of artificial respiration without interruption. Matters such as clearing debris from the mouth, pulling out a swallowed tongue, keeping the area about the mouth clear so that no foreign matter is taken in, loosening clothing which restricts breathing, removing wet clothing and keeping the patient warm are vital, but they should be done without interrupting the rhythm.



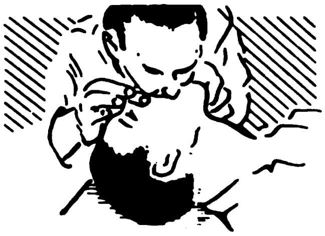
Thrust head backward.



Lift tongue and jaw.



Pinch nostrils.



Blow into patient's mouth.

The patient should not be given any food or liquid until he is fully conscious. The artificial respiration should be performed on the scene if possible. Once breathing is restored, the patient should be transported on a stretcher for further medical attention.

HOW TO USE THIS TRAINEE'S GUIDE

PUBLICATION

This Trainee's Guide has been prepared for use in Navy Fire Control Technician Schools.

TRAINING GOALS

This course material is divided into sections which are further divided into topics. The training goals are stated at the beginning of each topic, with a brief outline of the discussion points to be covered by the instructor.

STUDY ASSIGNMENTS

Self-study assignments serve to supplement classroom instruction. The trainee is urged to reinforce his knowledge by reading study assignments during class study periods or when otherwise scheduled by the instructor.

QUIZ SHEETS

A Quiz at the end of each section is to be completed as directed by the instructor. Do not mark this book - write your answers on a separate sheet of paper.

SAFETY PRECAUTIONS

Read the SAFETY NOTICE carefully. Develop safe working habits and practice safety always. Take time to be safe.

RECORD OF CHANGES

Number or Description of Change	Made by	Date

Section 1

INTRODUCTION TO TEST EQUIPMENT

Topic No.	Topic Title	Page
1.	Course Objectives	2

TOPIC 1: COURSE OBJECTIVES

You Are Now Going to Learn:

1. The objectives of this course.
2. The importance of test equipment to the FT.
3. The use of performance testing in this course.

Discussion Points for this Topic Are:

1. Your progress up to now.
2. Your future in test equipment.
3. What you will learn here.
4. Performance test procedures.

INFORMATION AND DISCUSSION:

YOUR PROGRESS UP TO NOW

Up to this point in FT "A" school, you have had numerous opportunities to use test equipment of various kinds. You have already made some checks, tests and adjustments using meters, oscilloscopes, synchro testers, function generators, absorption wavemeters, and condenser substitution boxes.

Some of this test equipment you have actually used, and some you have only seen demonstrated. Usually, your instructor taught you only enough basic information about the test equipment to enable you to just barely operate it. This was necessary at the time because you did not have the electronic background to learn the inner workings of most of the test equipment.

During this time, you have performed numerous experiments and performance tests. You have used voltmeters, ohmmeters, and ammeters to measure values of AC and DC voltages, resistance and current, and the oscilloscope to observe and check waveforms. You have also checked frequency using an audio signal generator as a reference.

In Basic Electronics, an absorption type wavemeter was used to measure the frequency of the Armstrong and Hartley oscillators. In Servo Systems, a function generator was used that could generate either sine or triangular waveforms. Another type, called a square wave generator, was used to check the frequency response of the video amplifier in Basic Electronics.

YOUR FUTURE IN TEST EQUIPMENT

Any fire control equipment is only as efficient as the test equipment used in its maintenance. Proper operation and knowledge of test equipment use must become one of your skills in order that you can be effective as a technician. Some of the test equipment you may be called upon to operate in the near future is more complex than complete radar systems were not too many years ago. Some of the oscilloscopes you will study soon make a television receiver seem simple by comparison.

Finally, some of the newer, more sophisticated fire control systems have automatic test equipment built right in to help you locate casualties. These must be maintained also, and it will be your job to be ready for anything that comes up.

WHAT YOU WILL LEARN HERE

Previously in this school, when you used a piece of test equipment, you assumed it was operating properly and was correctly calibrated. It was someone else's responsibility to insure that this was true. In the future, you, as the Fire Control Technician, must be able to recognize faulty performance of test equipment and take corrective action where practical.

Your goal here is to acquire skill in operating and learning to recognize correct performance in some of the following test equipments:

1. Multimeters or Volt-Ohm-Milliammeters (VOMs).

2. Vacuum Tube Voltmeters (VTVMs).
3. Impedance Bridges.
4. Transistor Testers.
5. Oscilloscopes.
6. Signal Generators.

Because of time limitations, you will spend most of your time on one particular model of each type of test equipment. There will be information available on other types if needed. Thorough knowledge of a particular piece of representative test equipment makes it much simpler to learn other models of that type later.

In this section you will perform many experiments, using various types of test equipment. You will analyze the loading effects of test equipment on the circuits you studied in FC Electronics. You will learn how to determine frequency, make phase comparisons and measure voltages using oscilloscopes. You will learn how to interpret Lissajous patterns, and how to calibrate and use several of the more complex precision oscilloscopes and synchroscopes. Finally, you will learn how to make measurements with a precision R-C-L Bridge.

Aboard ship, in your rating, you will be assigned to help maintain and operate a particular equipment of a missile or gun fire control system. These equipments, part of the ship weapons system, must be kept in top notch operating condition at all times. To do this, you must know the equipment, the checks of its performance, and how to locate and repair the casualties that occur. TEST EQUIPMENTS ARE THE TOOLS OF YOUR TRADE. You must know how to use them to check and repair the equipments of your assigned system.

If it is necessary to take time to study test equipment and its setup, before troubleshooting, it will result in distraction from casualty analysis and increased down time of your system.

The knowledge and skill gained from performing the following experiments will help prepare you for your assigned task aboard ship.

PERFORMANCE TEST PROCEDURES

A series of performance tests is part of this course. A performance test is a test designed to measure the ability of a trainee to accomplish a certain task in a specified amount of time. The Navy's Physical Fitness Program uses this type of test.

The test itself is a task that you should be able to do. It measures, under controlled conditions, how well you follow procedure, your care of equipment, your adherence to prescribed Safety Precautions, and your degree of learning. It will always be a task that prior training has prepared you for.

In this course of training, Performance Testing provides the instructor, AND YOU, with means of determining the degree of learning you have acquired. Performance Testing points up the need and importance of the text and associated experiments.

During a performance test, each trainee does the same task under the same controlled conditions. Your instructor supervises each trainee and does the grading. A second instructor may supervise other trainees in study or experiments while performance testing is in progress.

Any time after an area or an equipment has been covered or presented, you may be called upon to do a performance test in that area or with that equipment. Generally, this will be at the end of a topic in this Trainee's Guide.

A sufficient amount of time is allotted for performing a given test. If you understand what is expected of you, you should encounter no difficulties. Before each test you will be issued a Trainee's Instruction sheet. Your instructor will also answer any questions that you may have at that time.

Section 2

METERS

Topic No.	Topic Title	Page
1.	Basic Meters	6
2.	Multimeters	12
3.	C, L, and R Bridge ZM-11/U	38

TOPIC 1: BASIC METERS

You Are Now Going to Learn:

1. The operating principles of some of the basic meters.
2. How basic meters are modified to be more versatile.

Discussion Points for this Topic Are:

1. General.
2. DC Microammeter.
3. DC Ammeter.
4. DC Voltmeter.
5. Ohmmeter.
6. Rectifier-type Meter.
7. Review and summary.

INFORMATION AND DISCUSSION:

GENERAL

Meters come in many sizes, shapes and prices depending upon the use to which they will be put and the amount of money to be spent on them.

Laboratories frequently use expensive highly sensitive, single-function meters such as a current measuring galvanometer. The general technician however, is more apt to be using a relatively inexpensive multipurpose multimeter.

The type used is dictated by the requirements of the job and user.

To begin our study of meters we will review the principles of operation of the three basic meters that you studied in electricity. These are the Ammeter, Voltmeter and Ohmmeter.

DC MICROAMMETER

The D'Arsonval meter movement used in a DC microammeter consists of (1) a stationary permanent magnet and (2) a moving coil of very fine copper wire wound on an aluminum frame mounted in jewel bearings.

The operation of this type of galvanometer is based on the principle of motor action - that is, the action resulting from the flow of current in a movable coil suspended in a magnetic field. The movable coil consists of very fine copper wire wound on a rectangular bobbin that is pivoted and free to turn between the poles of the U-shaped magnet. To concentrate the magnetic lines of force, two soft-iron pole pieces are fitted to the magnet poles. A stationary soft-iron cylindrical core is mounted between these pole pieces and inside the movable coil. A small space in which the flux is uniformly distributed is thus provided between the pole pieces and the cylindrical core in which the coil may rotate.

When current flows through the coil, the motor action resulting from the magnetic reaction between the field produced by the moving coil and the field produced by the permanent magnet causes the coil and the pointer attached to it to turn. The deflecting force is proportional to the flux density, the current, and the dimensions of the coil. The deflecting force is opposed by the restraining force of two oppositely wound spiral springs, one on each side of the movable coil. Electrical contact with the movable coil is also made through the spiral springs. Thus, the coil does not continue to rotate as a motor, but turns until the deflecting force is balanced by the restraining force of the springs. Because the deflecting force is directly proportional to the current flowing in the coil, the amount of deflection is a measure of the magnitude of the current. A pointer attached to the movable coil moves over a calibrated scale and indicates the value of the current.

The restoring force of the spiral springs returns the coil and the pointer to the normal, or zero, position when the current through the coil is interrupted. If the instrument is not damped, the pointer does not go directly to its final position, but oscillates before coming to rest. Damping is accomplished by means of the aluminum bobbin upon which the coil is wound. As the bobbin moves through the magnetic field, an emf is induced in it. Therefore, according to Lenz's law these induced currents flow in such a direction that their fields tend to oppose the motion. Because of this damping action, the pointer comes quickly to rest.

DC AMMETER

The microammeter discussed thus far can be used to measure only small direct currents because the size of the wire on the movable coil is usually quite small. To measure larger currents, shunts are connected across the coil. The shunt carries that part of the circuit current that is in excess of the current necessary for full scale deflection of the needle. In this manner the range of a meter may be built up to the desired current-measuring capacity. Before the required resistance of a shunt can be calculated, the resistance of the meter movement must be known.

For example, suppose it is desired to convert a 100 microampere D'Arsonval meter having a resistance of 100 ohms into an ammeter capable of measuring line currents up to 1 ampere. The meter deflects full scale when the current through the 100 ohm coil is 100 microamperes. Therefore, the voltage drop across the coil is IR, or

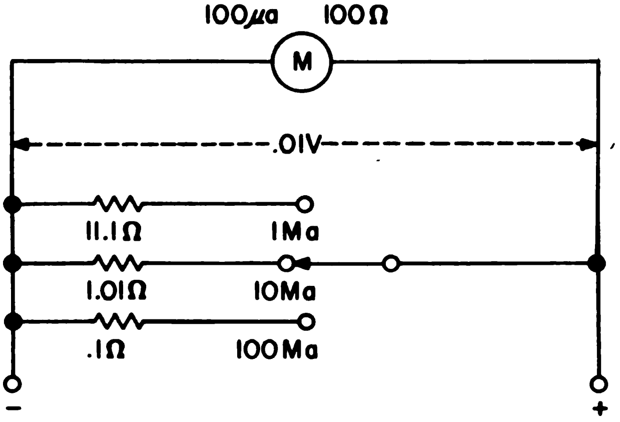
$$0.0001 \times 100 = 0.01 \text{ volt.}$$

Since the shunt and the coil are in parallel, the shunt will also have a voltage drop of 0.01 volt. The current that flows through the shunt is the difference between that necessary for full-scale deflection and the line current. In this case the shunt current is 1 - 0.0001, or 0.9999 ampere. The resistance, R, of the shunt is

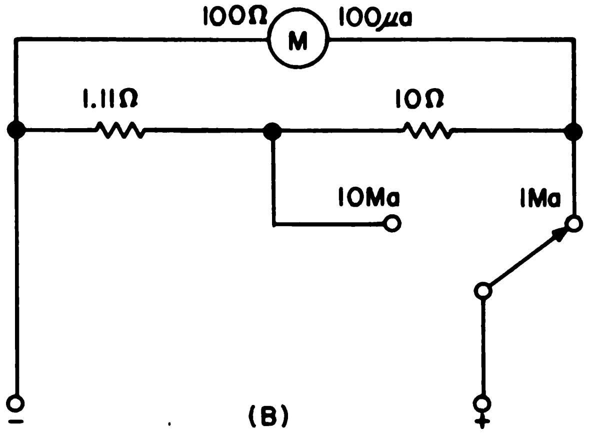
$$R = \frac{E}{I} = \frac{0.01}{0.9999} = 0.01 \text{ ohm (approx),}$$

and the range of the 100 microampere meter may be increased to 1 ampere by the addition of a 0.01 ohm shunt.

Various values of shunt resistance may be used, by means of a suitable switching arrangement, to increase the number of current ranges that may be covered by the meter.



(A)
SIMPLE ARRANGEMENT



(B)
PREFERRED ARRANGEMENT

1. AMMETER SHUNTS

Two such switching arrangements are shown above. (A) is the simpler of the two arrangements from the point of view of calculating the shunt resistors when a number of shunts are used. It has two disadvantages, however:

1. When the switch is moved from one shunt resistor to another the shunt is momentarily removed from the meter and the line current would then flow through the meter coil.
2. The contact resistance of the switch is in series with the shunt but not with the meter coil. In shunts that must pass high currents, the contact resistance becomes an appreciable

part of the total shunt resistance. Because the contact resistance is of a variable nature, the ammeter indication may not be accurate.

A more generally accepted method of range switching is shown at (B), illustrated in adjacent column. Although only two ranges are shown, as many ranges as needed can be used. In this type of circuit, the range selector switch contact resistance is external to the shunt and meter in each range position, and therefore it has no effect on the accuracy of the current measurement.

It is necessary for an ammeter to have low resistance in order to dissipate the least amount of power. Current measuring instruments must always be connected in series with a circuit and never in parallel with it. Obviously, if an ammeter were connected across a constant potential source of appreciable voltage, it would be the equivalent of a short circuit, and the meter would burn out.

DC VOLTMETER

The 100 microampere D'Arsonval meter used as the basic meter for the ammeter may also be used to measure voltage by placing a high resistance in series with the moving coil of the meter. The value of the series resistance is determined by the current needed for full scale deflection of the coil and by the voltage range. Because the current is directly proportional to the voltage applied, the scale can be calibrated directly in volts for a fixed series resistance.

For example, assume that the basic meter is to be made into a voltmeter with a full scale reading of 1 volt. Since the coil resistance of the basic meter is 100 ohms, and since 0.0001 ampere causes full scale deflection, the total resistance, R, of the meter coil and the series resistance is

$$R = \frac{E}{I} = \frac{1}{0.0001} = 10,000 \text{ ohms}$$

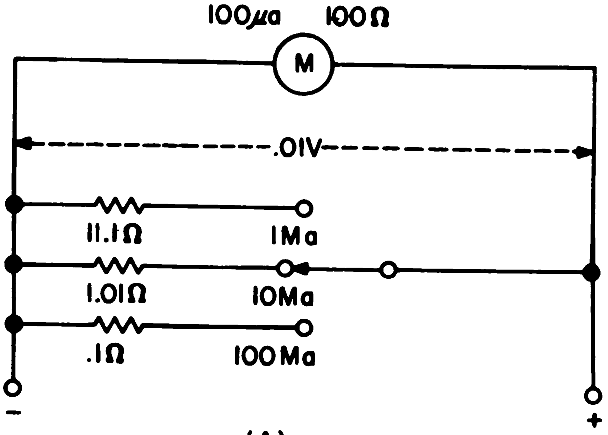
Since the moving coil has a resistance of 100 ohms, the additional series resistance (the multiplier) is

Multiplier R = 10,000-100 = 9,900

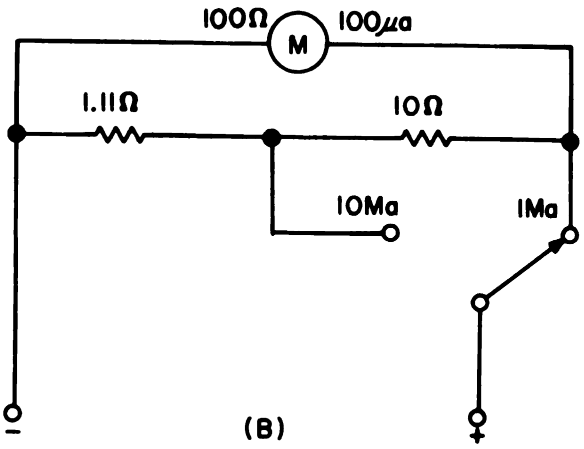
This condition is shown in the 1 volt branch of the circuit as illustrated on facing page. Other voltage ranges can be computed in the same fashion.

The sensitivity of voltmeters is given in ohms-per-volt, and may be determined by dividing the resistance of the meter plus the series resistance by the full scale reading in volts. This is the same as saying that the sensitivity is equal to the reciprocal of the current (in amperes).

Thus the sensitivity of a 100 microampere movement is the reciprocal of 0.0001 ampere, or 10,000 ohms-per-volt. The



(A)
SIMPLE ARRANGEMENT



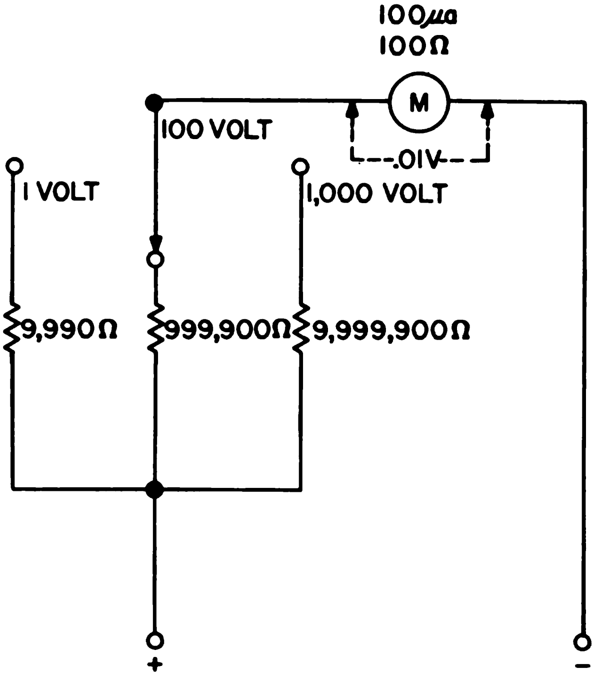
(B)
PREFERRED ARRANGEMENT

2. AMMETER SHUNTS

sensitivity of the meter depends on the strength of the permanent magnet field and the weight of the moving coil.

Multirange voltmeters utilize one meter movement and the required number of resistors that may be conveniently connected in series with the meter by a switching arrangement. A multirange voltmeter with three ranges is shown below.

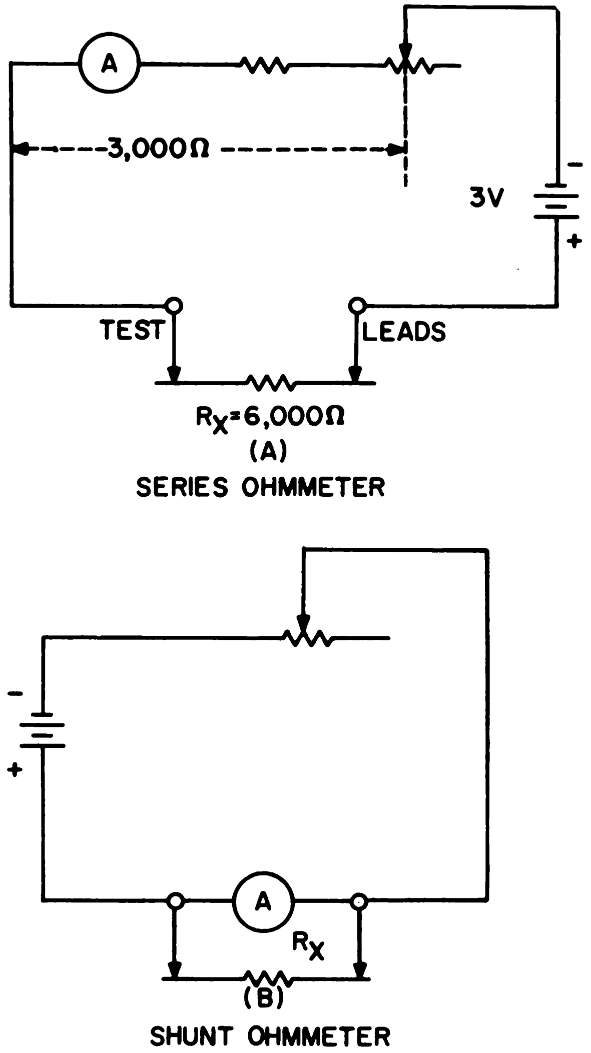
In precision instruments, the series resistors are usually wire wound and have a low temperature coefficient of resistance. Voltmeters are connected across (in parallel with) the circuit to be measured.



3. MULTIRANGE VOLTMETER

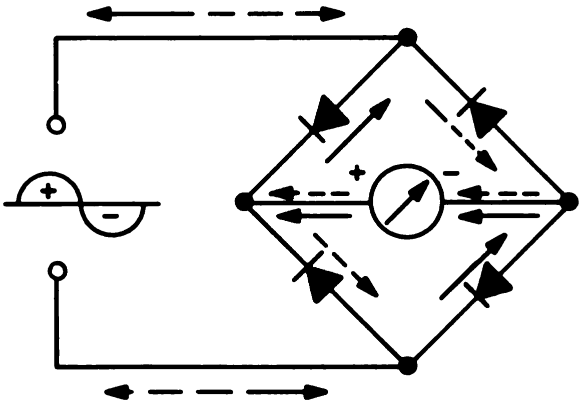
OHMMETER

The ohmmeter is widely used to measure resistance and to check the continuity of circuits and windings. The series ohmmeter consists essentially of a milliammeter, a voltage source, and a resistor, connected in series between the two terminals of the instrument, as shown at the right, at (A). Before the meter is used, the test leads are shorted together and the variable resistance is adjusted for full scale deflection. The point on the meter scale corresponding to full scale deflection is marked zero resistance. If a 1 milliampere movement is used with a 3 volt battery, the series resistance together with the meter resistance is 3,000 ohms. Part of the series resistance is made variable to compensate for changes in battery voltage.



4. OHMMETER CIRCUITS

When the unknown resistance R_X, is inserted between the test leads, the meter reading decreases. For example, a 6,000 ohm resistor (shown at (A)), inserted between the probes decreases the meter current to 0.33 milliampere. The corresponding point on the scale is marked 6,000 ohms. Other points may be similarly determined. Unlike the other meters considered thus far that



5. DIRECTIONS OF CURRENT FLOW IN AN AC METER DURING ONE COMPLETE CYCLE

have increasing values from left to right, the series ohmmeter has increasing values from right to left.

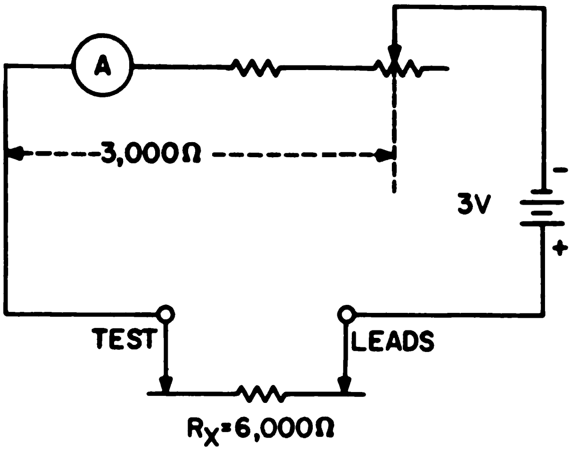
A shunt type ohmmeter circuit is shown at the right at (B). As in the series type, there is a variable resistor in series with the milliammeter. In this case, however, the test leads are brought out from the meter terminals, thus placing the unknown resistor in parallel with the meter instead of in series with it. The lower the value of the unknown resistor the lower is the value of the current that flows through the milliammeter. The higher the value of the unknown resistor the higher is the value of the current through the milliammeter. Thus, the shunt type ohmmeter reads up scale like a voltmeter or milliammeter.

As in the case of voltmeters and ammeters, shunts and multipliers are used to cover additional ranges of resistances. The series type of ohmmeter is used to measure high resistances, and the shunt type, low resistances.

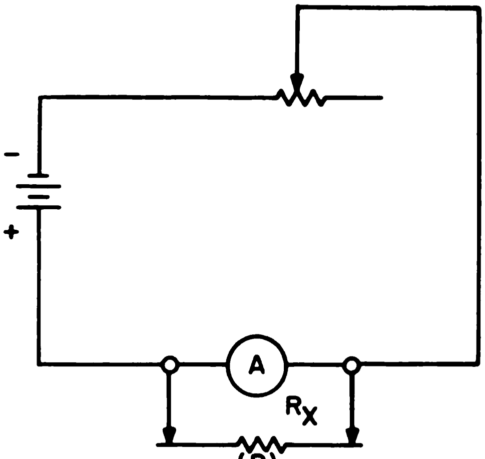
RECTIFIER-TYPE METER

Up until now we have only been considering DC instruments. These instruments will also measure the effective or RMS value of an AC voltage or current. The method of doing this is relatively simple. Basically, an AC voltage applied to the meter is passed through a full wave rectifier. Thus, the resultant current flowing through the movable coil is the average DC value of the AC waveform. This average DC current is the .636 value of the peak AC voltage. Because the RMS or .707 value of AC is the most desired AC reading for most purposes, it is the usual practice to calibrate a rectifier meter so that its scale reads the RMS value of the applied AC, and this value is equal to .707 of the peak value. Shown at left is a commonly used full wave, bridge type rectifier used in most present day meters.

It can be seen that because of the rectifiers, current will flow through the meter in the same direction regardless of the polarity of the AC sine wave input. This one way current is the average DC current of the AC waveform. Only one more thing has to be



(A)
SERIES OHMMETER



(B)
SHUNT OHMMETER

6. OHMMETER CIRCUITS

done to this circuit to make it an AC voltmeter. That is the additional adding of multiplier resistors for different ranges. One characteristic of an AC rectifier meter is that the rectifiers have a certain amount of internal resistance, even in the forward direction. This value varies inversely with current flow through the rectifier. It is usually compensated for in the selection of multiplier resistors.

The rectifiers themselves are low voltage, low current types so their size can be made very small.

A major disadvantage of an AC meter is its frequency response. The plates of the rectifier form relatively large values of capacitance. This is generally negligible at Audio frequencies up to about 20,000 cps, but from there up, the capacitance shunts more and more of the signal around the meter. Thus, at higher frequencies, the readings are very erratic and can not be depended upon to be accurate.

REVIEW AND SUMMARY

In this topic you reviewed some of the basic meters that you studied in Basic Electricity. These included the following:

1. DC Microammeter.
2. DC Ammeter.
3. DC Voltmeter.
4. Ohmmeter.
5. Rectifier type meter.

Each of these meters was studied separately as though it were only performing one function. In the next lesson you will learn that all of these different meters can be combined into a single but multifunction instrument known as a Multimeter. It is probably the most frequently used piece of test equipment.

TOPIC 2: MULTIMETERS

You Are Now Going to Learn:

1. Operating principles of the Volt-Ohm-Milliammeter (VOM).
2. Multimeter sensitivity and loading effect.
3. Operating principles of electronic multimeters.
4. Description and use of multimeter accessory probes.
5. The proper usage of multimeters.

You Will Acquire Skill in:

1. Recognizing meter loading of a circuit.
2. Measuring voltages and resistances with the VOM.
3. Measuring voltages and resistances with the VTVM.
4. Using safety precautions while measuring high voltages.

Discussion Points for this Topic Are:

1. General.
2. Volt-Ohm-Milliammeter (VOM).
   a. Functions.
   b. Accessory probes.
3. General instructions for using the VOM.
4. Electronic Multimeters.
   a. General.
   b. The basic DC VTVM.
   c. Bridge type VTVM.
   d. Accessory probes.
5. Transistor Multimeters.
6. Experiments.
7. Review and summary.

INFORMATION AND DISCUSSION:

GENERAL

During troubleshooting, a technician is often required to measure voltage, current, and resistance. To eliminate the necessity of obtaining three or more meters, the multimeter is used. The multimeter combines a voltmeter, ammeter, and ohmmeter in one unit. It includes all the necessary switches, jacks, and additional devices. By proper arrangement of parts, the multimeter can be built into a small, compact unit utilizing one meter movement.

A typical multimeter circuit is shown on the facing page. A three range voltmeter (DC and AC), a three range milliammeter, and a two range ohmmeter are combined in this circuit.

A 0-500 microampere meter movement with a resistance of 100 ohms is the basic meter movement for the multimeter.

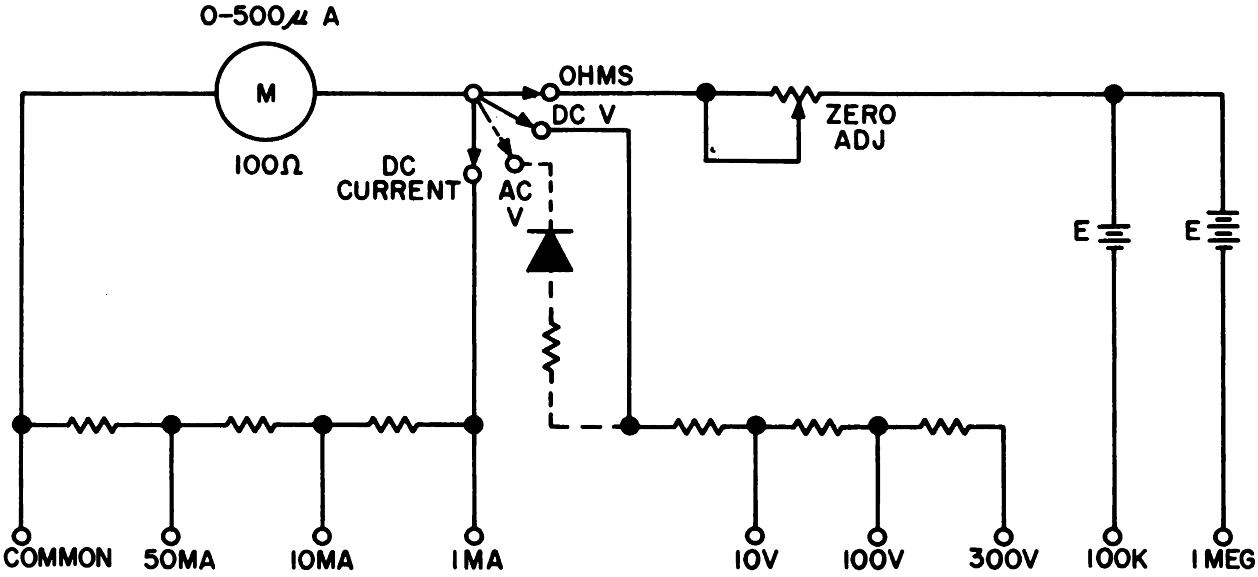
A more general use multimeter would probably have a 50 microamp meter movement and five to ten ranges for each function. The AN/PSM-4 that you have been using in past weeks is of this type.

VOLT-OHM-MILLIAMMETER (VOM)

The VOM in general use in the Navy is of the multifunction, multirange type. Multifunction means that they are designed to read AC or DC voltage, Direct Current and DC Resistance. Multirange means that these quantities can be measured in different ranges or scales, allowing for more accuracy and broader application.

Since there are many different types of these meters presently in use, this discussion will cover a VOM'S general description.

Some VOMs have only one main rotary switch which is used to change both the function and range scale of the meter. More commonly found, will be the type with two



7. TYPICAL MULTIMETER CIRCUIT

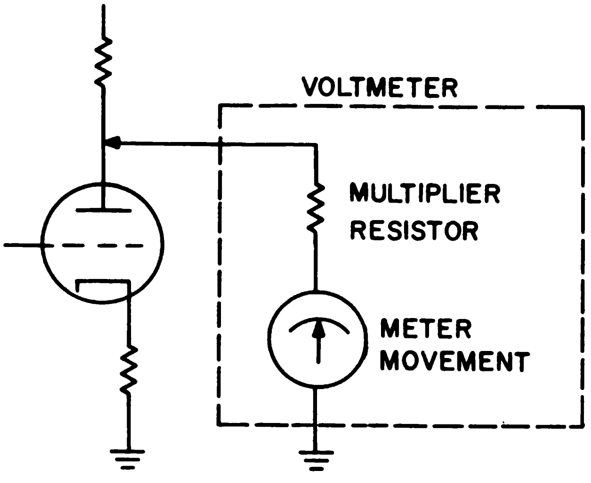
rotary switches, one for setting the function and the other for selecting the range. In addition you will normally find; a ZERO ADJUST CONTROL for zeroing the meter; banana jacks or phone tip jacks for plugging in test leads, and in many meters an OHMMETER ADJUST CONTROL for zeroing the Ohmmeter section to the condition of the batteries.

The face of the meter usually has a scale available for each setting of the function and range switches. Occassionally a single scale will be used for more than one function. A short study of the scales should be sufficient to determine how they will be used. Care should always be taken so that readings are from the proper scale.

Some VOMs such as the AN/PSM-4 have a HIGH VOLTAGE accessory probe. Special precautions must be observed when using this probe. Its use will be studied a little later.

One of the most important features to look for in a VOM is its sensitivity. By this is meant, how accurate its voltage readings will be on various scales. You may have heard one of your instructors refer to a meter as a 20,000 ohm-per-volt meter. What does this mean? Recall from your previous studies how a voltmeter is hooked up internally. You may remember that it consists of a multiplier resistor(s) and a meter movement in series. Whenever a voltage is to be measured, this circuit is paralleled with the circuit whose voltage is to be read, as shown below.

This parallel hookup will decrease the total resistance of the circuit somewhat. If the internal resistance of the meter is very high, the effect on the circuit is negligible. However, if the internal resistance of the meter is low, it will load down the circuit and the reading will not be accurate.



8. BASIC VOLTAGE MEASURING CIRCUIT

A 20,000 ohms-per-volt meter will have an internal resistance of 20,000 ohms for each volt on the range it is set on. For instance, when it is set on the 10 volt range, it will have 10 X 20,000 or a total internal resistance of 200,000 ohms.

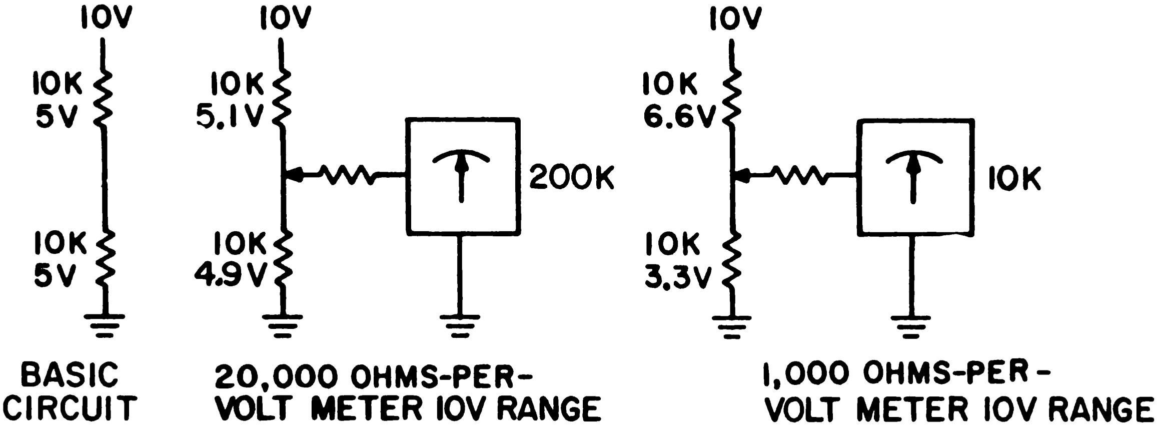
A 1000 ohms-per-volt meter only has an internal resistance of 10,000 ohms (10 X 1000) when set on the same range. It is shown below how these two meters would affect the same circuit. The 20,000 ohms-per-volt meter would affect the circuit very little and its reading would be more accurate. The reading on the 1,000 ohms-per-volt meter would be very inaccurate, even in this low impedance circuit. Therefore, the higher the ohms-per-volt rating of the meter, the more accurate the voltage readings will be.

A VOM uses battery power for resistance readings. In some meters a low voltage battery will be employed when the meter is set on the low resistance ranges and a higher voltage battery is employed when the meter is set on the high resistance ranges. On most meters, there is only one resistance scale. The resistance is found by multiplying the scale reading times the multiplication factor at the range switch settings.

CAUTION

Since resistance readings are taken using a low voltage battery as a power source, the series resistance of the meter is necessarily low. Never place the meter across an energized circuit when the function switch is set for resistance. To do so will result in serious damage to the meter, since the low series resistance can not limit current to a safe value. The low value precision series resistor and/or the meter movement will burn out and the meter needle may be bent by hitting the peg. This is by far the most common cause of meter failure. Always check for voltage before taking resistance readings on a circuit. Upon completion of resistance readings, secure the meter on the high range AC function.

OUTPUT voltage measurements are made to determine the amount of AC voltage alone which is present in a mixture of AC and DC voltages. A capacitor is switched in to the regular AC ranges of the meter and prevents any direct current from flowing through the meter circuit due to the applied signal. Since this capacitor is in series with the input voltage, some part of the AC voltage will be dropped across its reactance, and the meter indication will be affected for all readings. The amount of error which the capacitor introduces into the circuit varies


10V
10K
5V
10K
5V
BASIC CIRCUIT
10V
10K
5.1V
10K
4.9V
200K
20,000 OHMS-PER-VOLT METER 10V RANGE
10V
10K
6.6V
10K
3.3V
10K
1,000 OHMS-PER-VOLT METER 10V RANGE

9. VOM CIRCUIT LOADING EFFECTS

with the input frequency and with the instrument range which you are using. Higher frequencies and higher ranges produce less error. Most meters supply a correction factor with their literature which you may apply to make your readings more accurate.

Some multimeters provide for measuring higher voltages by means of a high voltage probe. The AN/PSM-4 which you have been using is a good typical example of this.

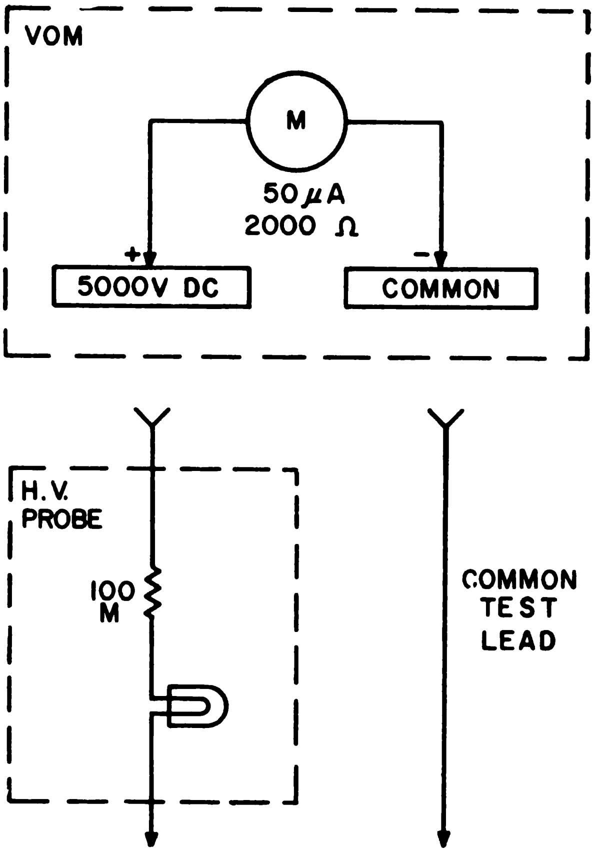
The high voltage probe, complete with its own lead, is to be used with the standard black test lead for measuring DC voltages on the 5000 volt range. One end of the lead has a threaded tip which screws on over the post in the face of the instrument labeled +5000 VDC MULTIPLIER. The other end of the lead has a high voltage multiplier assembly made of red plastic with a clear plastic end, and terminates in a crocodile clip at the end of a short piece of flexible wire. The clear plastic end allows a glow from the neon lamp to be seen when high voltage is applied to the lead and to the instrument circuit through it. This is a warning to the operator that there is dangerous high voltage present at the crocodile clip, and that he should not touch the clip while the voltage is still present. The circuit at right shows how the HV probe is connected to the meter. It is directly in series with the meter movement. There is a 100 Megohm resistor in the probe which at 20,000 ohms-per-volt will enable us to measure up to 5000 V.

The major disadvantages of the VOM are the loading effect of the low range scales when used to measure voltage across high impedance circuits, and the varying accuracy at different frequencies on AC or OUTPUT functions.

In summation it can be said that the VOM is a very handy, versatile, and usable unit of test equipment. It can be used for AC, DC, and OUTPUT voltage, DC current, and resistance measurements. It is small and easy to move about, and requires no external power source. This makes it especially useful aboard ship.

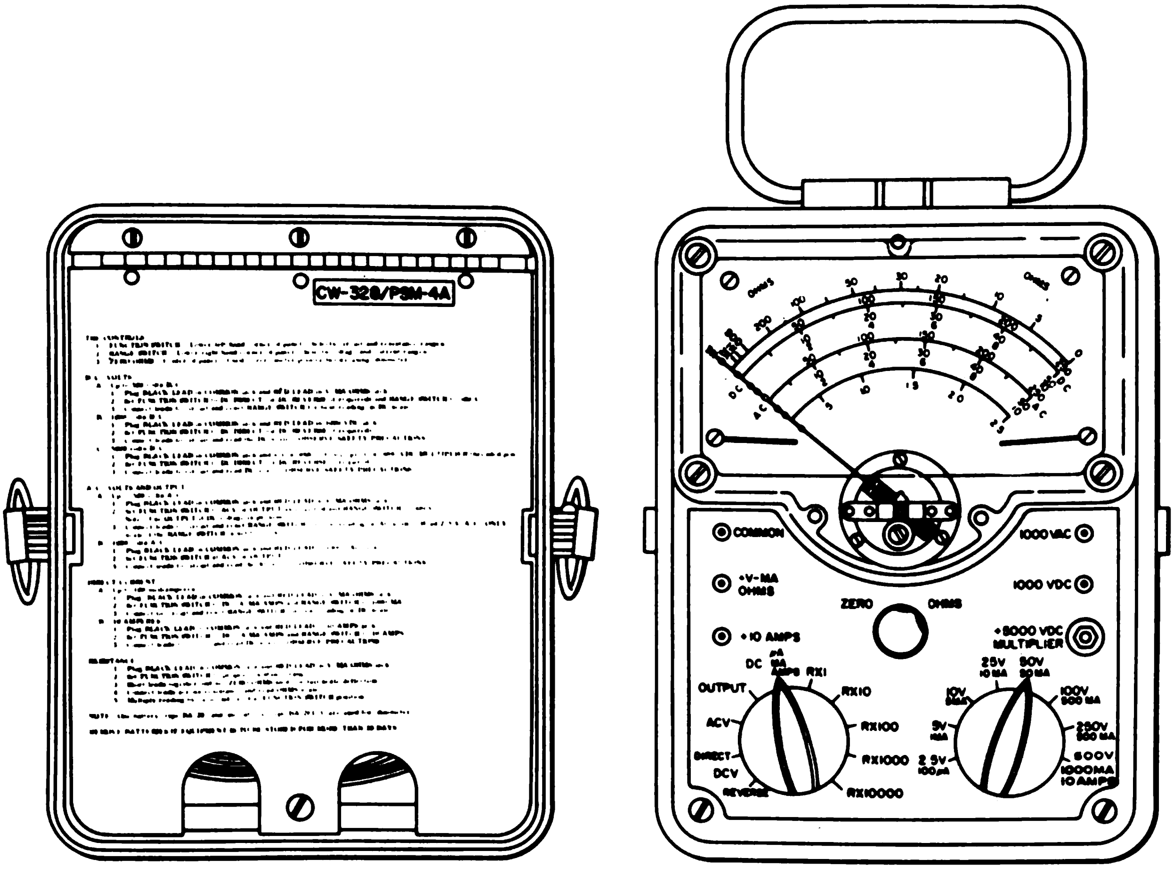
GENERAL INSTRUCTIONS FOR USING VOM

1. Always check meter function setting carefully before taking a reading.



10. HIGH VOLTAGE MEASURING CIRCUIT

2. Always start at the highest range practical to prevent pegging the needle.
3. Check the meter for zeroing.
4. When reading resistance, check zeroing each time range is changed.
5. When taking DC readings, if polarity is unknown, touch probes to circuit under test to check for proper deflection of the needle with range set to the highest scale.
6. Always take readings looking straight into the meter, not at an angle, to eliminate parallax.
7. For final readings use the range that gives readings in the upper end of scale for greater accuracy.
8. Do not leave meter on a resistance range when not in use. This can drain batteries if leads short together.



11. MULTIMETER AN/PSM-4A, FRONT VIEW WITH COVER OFF AND REVERSED

ELECTRONIC MULTIMETERS

GENERAL - One of the most helpful developments in meter type measuring devices for testing electronic equipment, is the incorporation of the vacuum tube in the measuring instrument itself. The basic meter movement is connected into a vacuum tube circuit in such a way as to indicate a current which is proportional to the signal applied between the test prods. The Vacuum Tube Voltmeter (VTVM) achieves its main advantage over the ordinary multimeter because it isolates the meter movement from the circuit under test; and by utilizing the vacuum tube's capabilities as an amplifier and rectifier. These greatly increase the sensitivity of the measuring system beyond that established by the meter movement itself. Moreover, it extends the frequency range of the meter far up into the hundreds of kilocycles region. (Note: special probes may further extend these frequency limits to hundreds of megacycles.) Finally, it minimizes the loading effect of the measuring device on the circuit under test.

Another advantage of the VTVM is that the input impedance is not only high, but is constant for all DC voltage ranges; in contrast to the impedance of the multimeter which varies according to the full scale voltage being used.

Most VTVMs have an input resistance of about 11 megohms; laboratory types go much higher. Even in the 11 megohm units, this is equivalent to the input resistance of a 20,000 ohms-per-volt meter with a full scale range of 550 volts.

It is, however, on the low voltage ranges that the advantage of the VTVM is most apparent. For example, a typical 20,000 ohms-per-volt meter has an input resistance of only 0.2 megohms on the 10 volt scale; the constant 11 megohm resistance of the

VTVM on this scale is 55 times as high. Therefore, we can say that for low voltage measurements where sensitivity is important, the VTVM is by far the most useful and accurate type meter.

The VTVM operates on the principle that a change in grid voltage applied to a vacuum tube causes a change in plate current. Thus, by applying the voltage to be measured to the grid of a vacuum tube, we can measure the plate current change, and in a properly calibrated instrument can so determine the voltage we wish to measure.

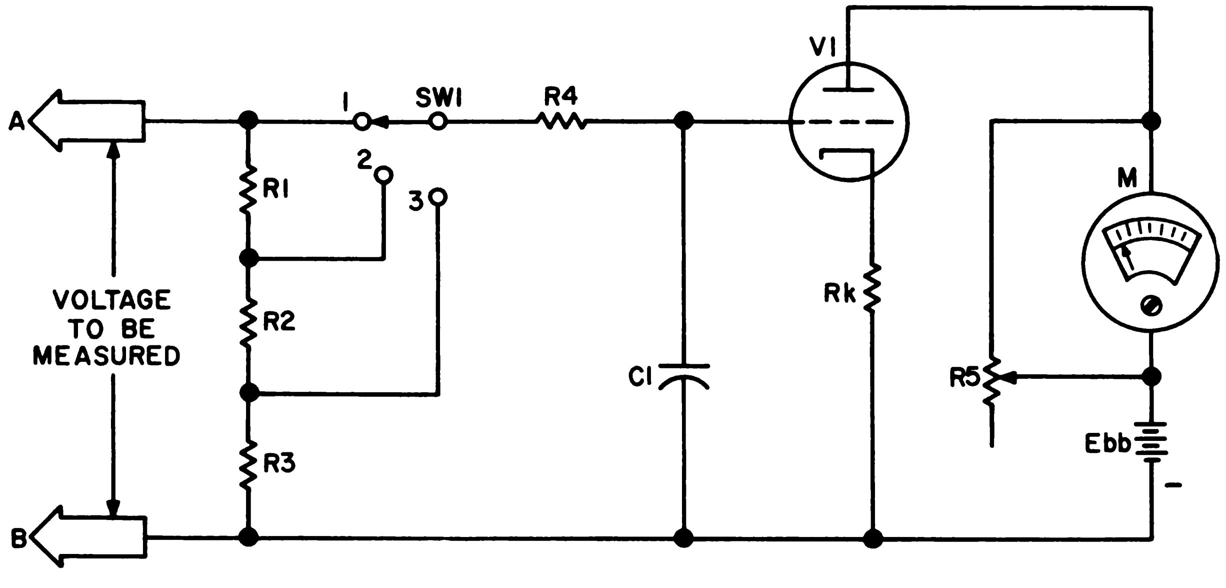
As should be done with any complex piece of equipment like the VTVM, we will first look at the basic operating principle of the device, and then study it section by section.

THE BASIC DC VTVM - the direct current VTVM is, in the main, an amplifying triode tube used in such a manner that the DC voltage to be measured causes a change in its plate current. This current is indicated on a moving coil meter. The voltage to be measured is applied to the control grid circuit of the vacuum tube; it offsets the operating bias and so changes the plate current to above or below the no input voltage value. When the plate current meter is suitably calibrated, its indications are interpretable directly in values of applied input DC voltage.

Shown below is the circuit for a basic DC VTVM. It is not the circuit you will find in most commercial VTVMs, but it illustrates the basic operating principle of a VTVM and shows why a VTVM has such a high sensitivity.

The circuit to be tested is connected between the two test prods, A and B. This applies the voltage to be measured across R1, R2, and R3. This voltage becomes the grid potential of V1. This means that the Ip of V1 is proportional to the voltage to be measured. The Ip of V1 flows through the meter movement, causing the meter to deflect. As in any vacuum tube amplifier though, this Ip comes from the Ebb power source, not from the grid signal circuit. The grid merely controls it. Therefore, the only current drawn from the circuit across the test prods is the very small current in R1, R2, and R3, and since they have extremely high resistance (10-15 megs), only a very small current is drawn from the circuit under test. That is the main reason for the high sensitivity of the VTVM.

Be sure you understand the basic operating principle of the VTVM. The voltage being measured is developed across a very high resistance. Then this voltage is fed as a signal to the grid of a vacuum tube, to control the tube plate current. Finally, the tube Ip is fed to a meter which registers the voltage being



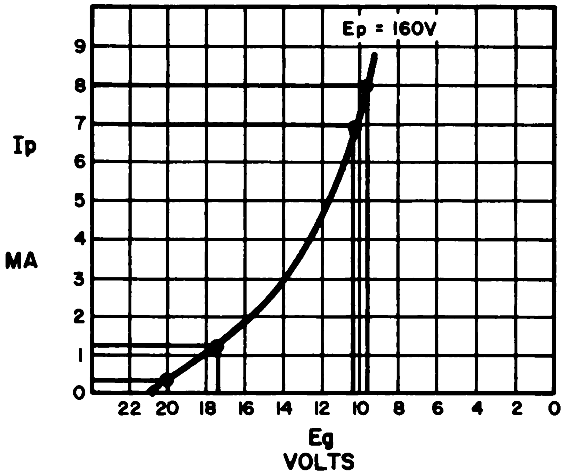
12. THE BASIC DC VTVM

measured. Remember, the VTVM essentially has two circuits. One circuit is the high resistance between the test prods and includes the tube grid circuit. The other carries the Ip and includes the tube, the meter, and the power source.

Going back to the illustration on the previous page, R4 and C1 make up a filter for the grid input. This filter removes any AC ripple from the input. R5 is the zeroing adjustment for the meter, and is adjusted to bypass the small Ip when there is no circuit across A and B. Rk is the bias resistor for V1. The bias across Rk very nearly cuts off the Ip when there is no circuit across the test prods. Taps 2 and 3 in the voltage divider are used to extend the range of the meter. For example, tap 1 is used for voltages from 0-5 volts. Tap 2 is used for voltages from 0-50 volts and tap 3 is used for voltages from 0-500 volts.

The simplified circuit just studied was an extremely simplified circuit for explanation purposes only and would not be practical as an operating VTVM. For one thing, any one tube VTVM has inherent inaccuracies. One of the most important of these is shown below.

The simplified VTVM can only be accurate when the plate current of the tube is directly proportional to the grid voltage. In the curve shown on this page Ip is not always directly proportional to Eg. Compare points 1 and 2 to 3 and 4. At points 1 and 2, a change in Ip of one milliampere is produced by a change in Eg of almost 3 volts. At points 3 and 4, a change in Ip of one milliampere is produced by a change in Eg of only about 0. 5 volts. It is actually the low end of the curve that is most nonlinear. This nonlinearity near the low end means that the scale calibration of the meter will be cramped at the low end to match the Ip-Eg curve. This also decreases the meter accuracy for measuring small voltages.



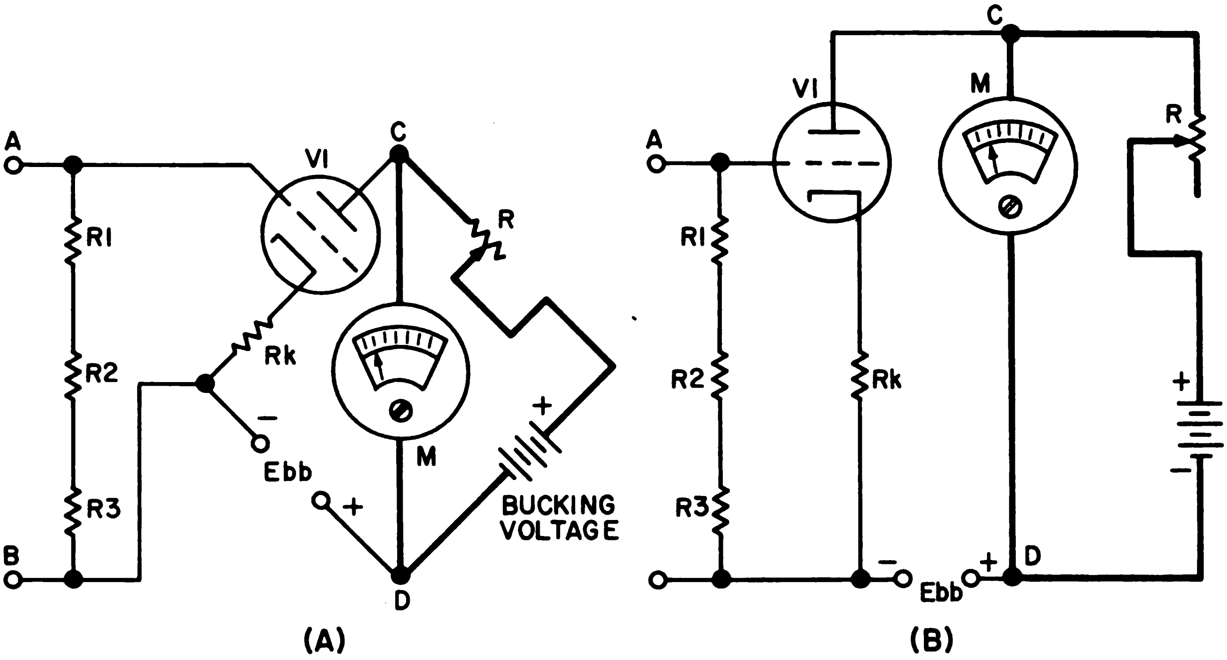
13. TYPIÇAL Ip-Eg CURVE FOR TRIODE

The curve also brings out another fault in the basic VTVM. It shows that Rk can never bias the tube at complete cutoff, at zero reading. No matter how large Rk is, the bias voltage will not cutoff Ip because there must be some Ip through Rk to furnish the bias voltage. Therefore, the simplified VTVM cannot be accurately zeroed. That makes two main disadvantages; (1) cramped scale at the lower end, and (2) inaccuracies in zeroing.

These inherent disadvantage of the basic circuit can be overcome by some redesign of the basic circuit, keeping in mind at all times that our major goal is to keep the metering circuit isolated from the input circuit. This is a must, because the metering circuit is inherently a low impedance circuit and we wish to have a high impedance input for our meter. This we will do on the next few pages.

Shown at top of facing page is a circuit to eliminate the inaccuracies in the zeroing procedure. First, trace out the light lined circuit in (A), it is essentially the same as the simplified VTVM. Now trace the heavy lined circuit. This circuit adds a battery voltage across the meter in the opposite direction to the plate current of V1, thus bucking Ip. Now to zero the meter, simply adjust the rheostat R until the meter reads zero. Then the Ip is exactly cancelled by the bucking voltage. Naturally this is done with no signal applied to A and B. The potential difference between C and D is now zero and no current flows through the meter and it indicates zero.

At (B) is shown the same circuit drawn as it normally appears on a schematic. Compare the two and be sure you see they are identical. Notice that this is a bridge circuit. The battery and rheostat make one branch of



14. ZEROING THE VTVM

the bridge, and V1, Rk and Ebb form the other branch. When there is no voltage across A and B, the meter reads zero because the bridge is balanced. The meter will deflect under the influence of a voltage across A and B because the bridge will become unbalanced as a result of V1 conducting harder. This circuit is the heart of most of the electronic multimeters in use today. As you will see later, another tube is often used to refine it but the basic circuit is the same.

BRIDGE-TYPE VTVM

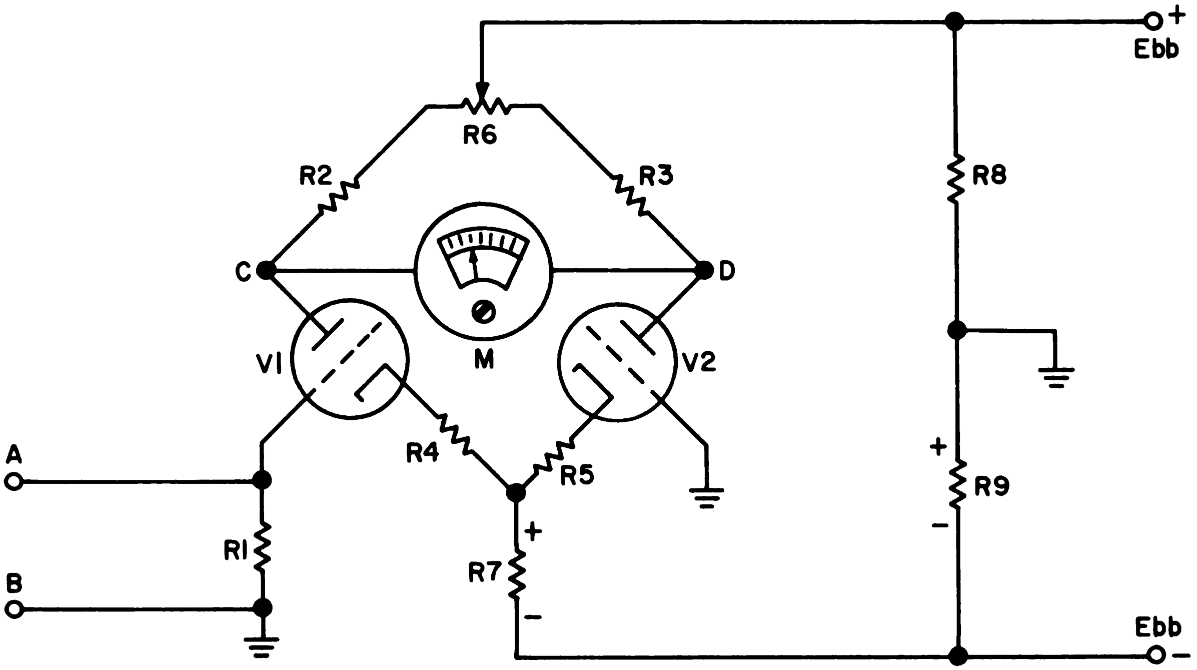
Now that we have studied most of the basic operating principles of a basic VTVM we will refine them and put them together in the circuit you will see in most VTVMs. This circuit is called a bridge type VTVM and is shown below.

This circuit has two vacuum tubes, one in each branch of the bridge. Go over the circuit carefully and check the tube connections also. Notice that V1 and V2 are biased equally by R7 and either R4 or R5, which are of equal value. Also notice that the grids of V1 and V2 are connected to opposite ends of R1. This means that the signals to them will essentially be 180° out of phase with each other. You ought to spot that set-up as a modified push-pull circuit.

There are three good reasons for connecting V1 and V2 in push-pull. First, the combined Ip-Eg curves of the two will be linear. This allows a linear calibration of the meter scale with no cramping at the lower end. Second, the circuit is more sensitive to voltages across R1 (a substitute for the input network), because one tube pushes and the other tube pulls. Third, the power supply drain is steady as in all Class A push-pull connections.

To understand how this circuit works, trace from the grids to the cathodes with no signal applied at A and B. From either grid to ground, through R9, then R7, and on through R4 or R5 to the cathodes. This gives the resultant grid voltage for no signal. For either tube, its the sum of the voltages across R9, R7, and either R4 or R5. R9 and R7 are equal but the drops across them are opposing and therefore will cancel each other. The resultant bias voltage on each tube is only the voltage across R4 or R5.

Since R4 and R5 are equal, the biases for V1 and V2 are equal. This makes the two Ips equal and points C and D are at equal potentials. With no potential difference across the meter, no current will flow through that leg of the circuit and the meter will read zero. That is the condition with no voltage applied to the test prods at A and B. Now we will apply a DC voltage to the points A and B and we will assume that A is positive and B is negative. The voltage across R1 is in V1 grid-cathode circuit and opposes the bias across R4. The grid of V1 goes more positive or less negative and the Ip of V1



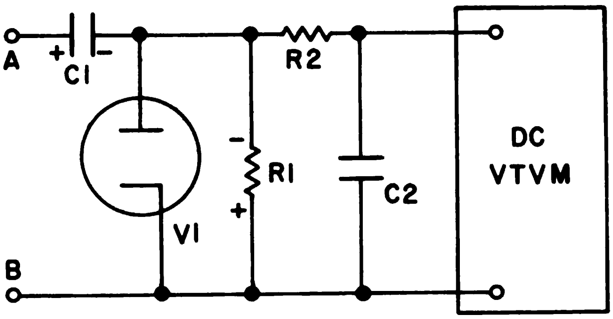
15. BRIDGE TYPE DC VTVM

increases causing point C to become less positive. At the same time the increased Ip increases the drop across R7. Now the R7 voltage more than cancels the R9 voltage. This causes the negative bias on V2 to be larger and reduces the conduction of V2. V2 plate goes more positive (point D) at the same time that point C was going less positive. This is push-pull action across the meter and the potential difference across the meter causes current to flow through the meter. This current flow is proportional to the size of the signal that was applied to the test prods. If the applied signal had been of the opposite polarity the tubes would have reversed their action and a current would have flowed through the meter in the other direction indicating a voltage of opposite polarity.

R6 is the balancing adjustment. It is adjusted so that points C and D are at the same potential for zero signal. With C and D at equal potentials the meter reads zero. R6 is needed because normal manufacturing tolerances preclude any possibility of getting perfectly matched components for the two halves of the bridge. This means that even with no signal applied the two tubes may not conduct identical amounts. R6 is adjusted to change the plate loads of the tubes and thus cause them to conduct equally for no signal in.

Up to this point we have only been considering a DC VTVM. For the instrument to be more useful it should measure AC voltages also. Let us examine the bridge type VTVM for AC operation. V1 and V2 are biased Class A which means they will amplify both alternations of any AC signal applied. This means that the Ip swings will be AC and the average value of an AC waveform is zero. Thus the meter will read zero when AC is applied.

There is only one way to measure AC with a DC VTVM. First, rectify the AC, then, apply the rectified voltage to a bridge type DC VTVM. Shown at right is the necessary additional circuitry to convert the VTVM to measure AC.



16. RECTIFIER FOR VTVM

The VTVM section in the square is a bridge type as covered earlier. Rectifying is done by V1 because it passes current only when the plate is positive. The necessary high impedance between A and B is obtained from R1 and C1 in the following manner. On the first few positive half cycles, current rushes through V1. This soon charges C1 up to the peak voltage of the input. C1 stays near this peak charge because R1 has a high resistance and delays the discharge. The high charge on C1 opposes any current flow through V1. In fact, current flows through V1 only on the very peaks of the positive half cycles. This current is very small, just large enough to restore the small charge that leaks off C1 during the negative alternations. This small current is the only current drain from the circuit across A and B. The R1-C1 combination thus furnishes the high impedance between points A and B.

Now look at the voltage developed across R1. This is the input voltage to the DC VTVM section. The voltage across R1 is a DC voltage because the current through R1 comes from the discharge of C1. It is slightly pulsating though. The pulses are caused by C1 charging on the AC peaks. These small pulsations are filtered out by R2 and C2, and make the final input to the DC VTVM section a smooth DC.

Be sure you understand why the voltage across R1 is DC. C1 maintains a constant polarity because it cannot discharge completely. This constant polarity charge on C1 develops the voltage across R1. Look at the figure again and check these polarities—they are labeled. Actually, the voltage across R1 is not the same as the voltage across A and B, but it is proportional to the A-B voltage. This makes it merely a calibration problem—the meter is calibrated to read the A-B voltage directly.

The additional circuitry needed to enable the VTVM to measure AC is switched in when it is needed by means of the Function switch of the meter.

Like most meters, the VTVM can also be connected to read resistance. Shown below is the basic circuitry necessary to enable the VTVM to become an Ohmmeter.

A voltage supplied by the VTVM power supply forces current through the unknown resistance, Rx, and through the scale multipliers. The amount of resistance in Rx determines the voltage developed across the scale multipliers. This voltage is the input to the VTVM section. In short, the size of Rx determines the input voltage to the VTVM.

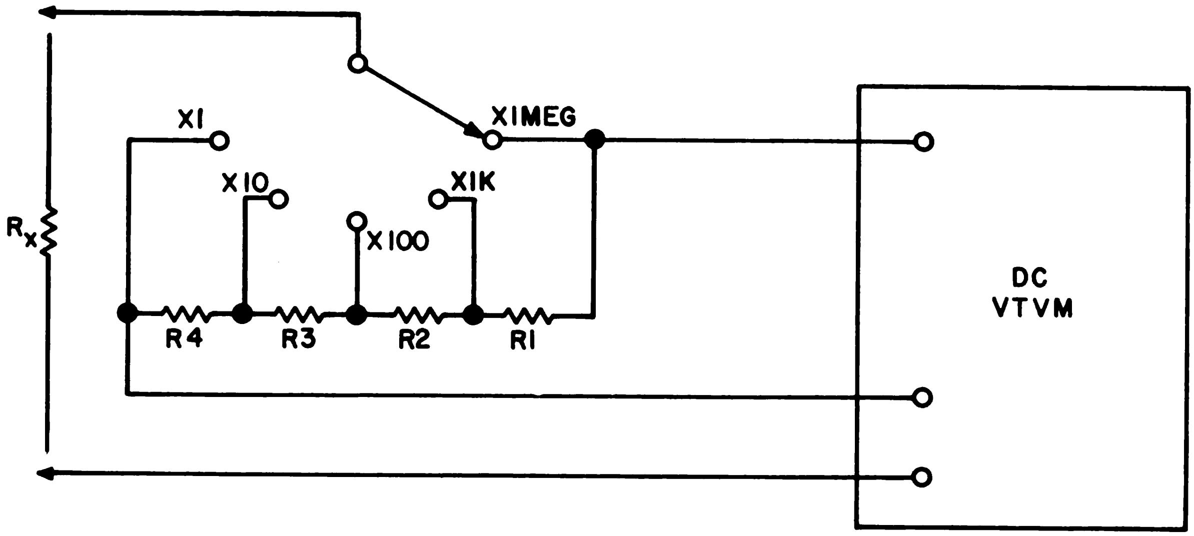
The meter scale is calibrated to read the voltage input as ohms. Then, if the R1 scale multiplier is used, the resistance is read directly. But, if one of the other scale multipliers is used, the meter reading must be multiplied by the multiplier.

Most VTVMs cannot measure current directly so this feature will not be discussed.

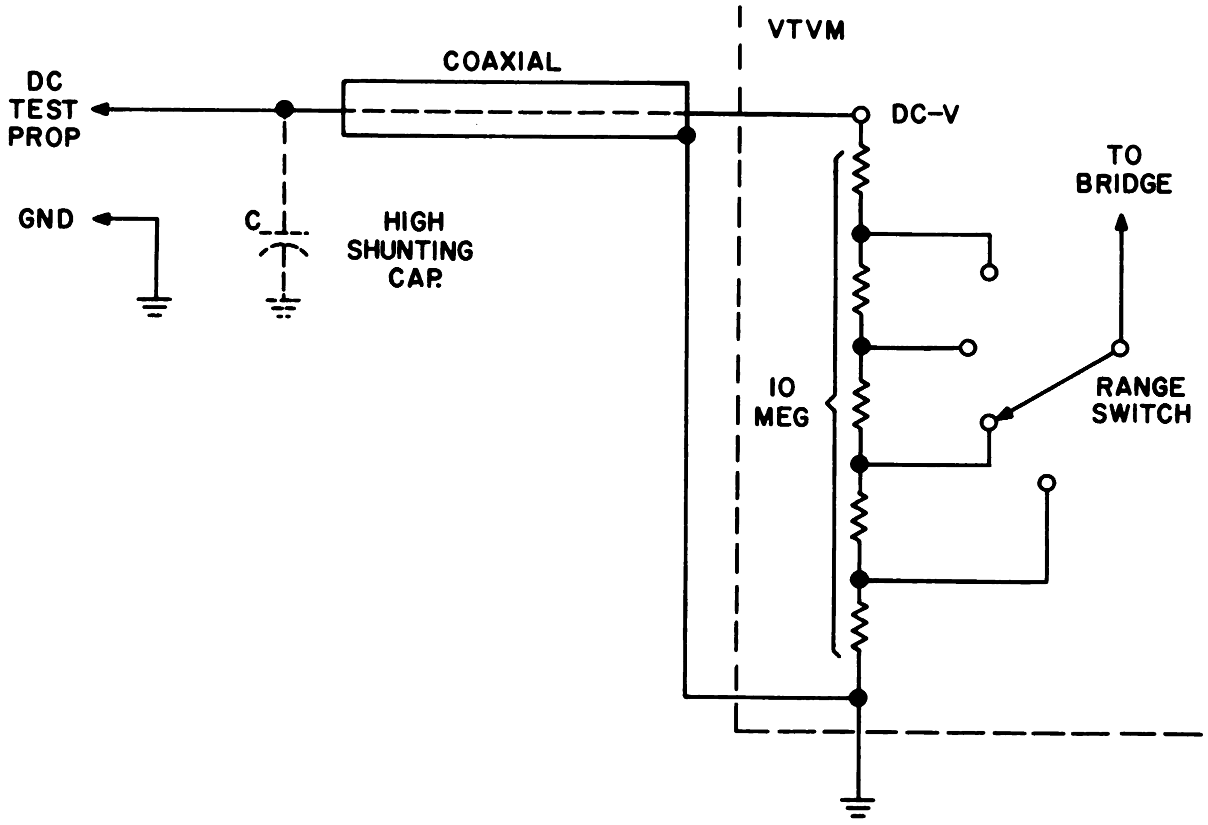
In the VTVMs that you will use, the AC, DC, and Resistance circuits are all incorporated into one compact instrument. Switches are provided for changing functions and ranges similar to the switches on the VOM. In general, the operation of the two instruments is the same except that the VTVM must normally have an AC power source available, although there are some few models that use battery power. This power requirement is the major disadvantage of the VTVM. Its high sensitivity on the low ranges is its biggest advantage over the VOM.

To help make the VTVM even more versatile, accessory probes are available to add additional uses and ranges to the meter. These will be studied next.

ACCESSORY PROBES—the prime purpose of test equipment used in checking electronic circuits is to show the technician a true picture of what is happening in the circuit under test. When test equipment is applied to a circuit, it becomes, for all practical purposes, an integral part of the circuit. Under certain circumstances this will have the effect of changing the operation of the circuit under test, and readings, on a scope or meter, taken under these conditions would not be a true indication of the circuit operation. For this reason it is sometimes necessary to utilize special probes to minimize the effect the test equipment has on the circuit. At this time we are only concerned with the probes used with the VTVM. We will study the three most important ones. These are the DC PROBE for circuit isolation, the RF PROBE for extending the upper limits



17. VTVM MEASURING RESISTANCE



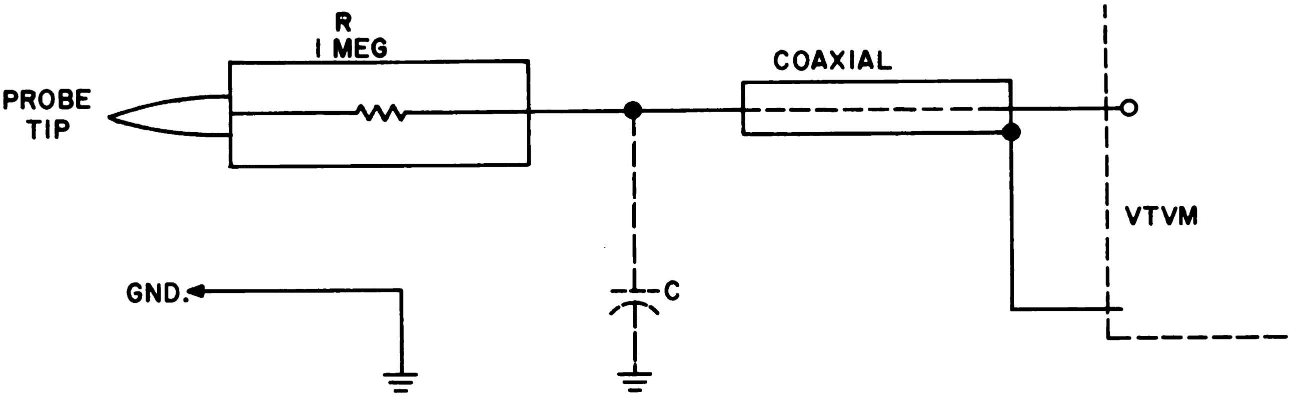
18. CAPACITIVE LOADING BY VTVM

of AC voltages (frequency limits) that we want to measure, and the HIGH-VOLTAGE PROBE which enables us to read much greater amplitude high voltages than just the basic meter.

The simplest and perhaps the most widely used DC circuit-isolation arrangement is that provided by the 1 megohm resistor which is included in the DC PROBE of practically all service type VTVMs, for use on the DC voltage ranges. This isolating resistor has two important functions: (1) it greatly reduces the effective overall input capacitance presented to the circuit under test by the VTVM; (2) it comprises part of a resistance-capacitance input filter circuit which filters out any strong high frequency AC components that may be present in the DC voltage that is to be measured, thus preventing them from reaching the metering circuit. Thus, DC voltages can be measured in the presence of high frequency AC.

The input voltage-divider resistance network, coaxial cable, and Direct probe of a VTVM have a combined overall capacitance which may total approximately 60-120 pf or more. If an isolation resistor were not used, this capacitance would be applied directly across the circuit whose DC voltage was being checked, as shown above.

Such a large value of shunting capacitance will cause severe capacitive loading and disturbance of the normal circuit operation of many of the r-f circuits whose DC voltages need to be checked with a VTVM, resulting in erroneous and misleading DC voltage readings. An example is provided by an attempt to measure the signal developed (grid leak) DC bias voltage at the control grid of a high frequency oscillator. It is not practical to dispense with the coaxial cable in an effort to reduce the capacitance, since excessive spurious voltages would often be induced in an unshielded cable by strong external fields.



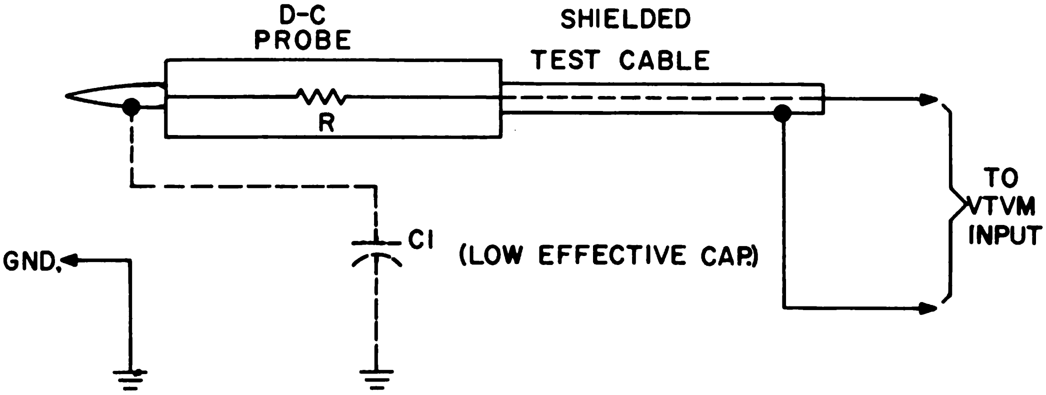
19. USE OF THE ISOLATING RESISTOR

The problem is solved by inserting a suitable isolating resistor R, as shown above, having a value of approximately 1 megohm, in series with the input circuit, between the coaxial cable and the test point in the receiver.

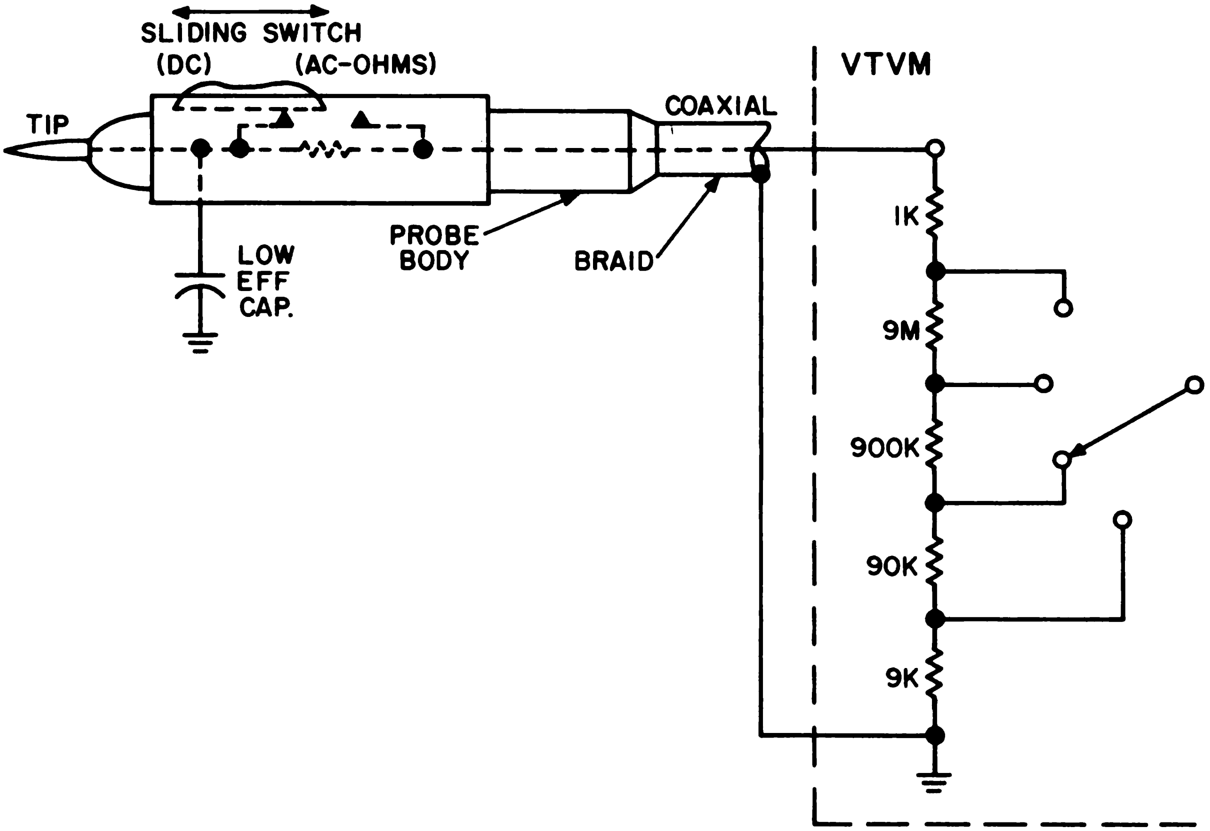
The effect of introducing the large value isolation resistance at this particular point in the circuit is to place it in series with the reactance of the overall input capacitance C. When a resistor is connected in series with a capacitor, the series combination has an impedance larger than the reactance of the capacitor alone, for any given frequency. Therefore, the addition of this isolation resistor greatly increases the impedance of the input circuit as seen from the probe tip. This is equivalent to saying that the input capacitance has been reduced in effect, to a value C1 (see below), whose reactance is equivalent to this impedance at the particular frequency being considered.

Another viewpoint regarding the effect of the isolating resistor is that its resistance value is sufficiently high (usually about 1 megohm) to provide protection against the shunting effect of the low impedance presented by the cable at high frequencies. The isolating resistor is between the high frequency voltages in the circuit under test, and the low impedance presented by the input end of the cable, which may drop to as low as 75 ohms at high frequencies.

Its practical effect is to provide negligible capacitive circuit loading and resonance effects for most VTVM DC voltage measurements made in radio frequency circuits, so that little or no detuning, or other disturbance, of such circuits under test is caused by connection of the DC probe of the VTVM to a load-sensitive point in the circuit. Addition of this 1 megohm resistor in series with the usual 10 megohm input network resistance of



20. EFFECTIVENESS OF ISOLATION



21. DC PROBE AND VTVM INPUT CIRCUIT

most VTVMs, results in a total DC input resistance of 11 megohms, which is great enough to prevent serious resistive loading of most tested DC circuits, including DC grid bias circuits.

The most satisfactory arrangement is to mount the resistor within the DC probe head as shown above. Reduction of the effective input capacitance at the probe tip to a value of only 1 or 2 pf is common. Of course, the probe assembly has a certain amount of stray capacitance from its input to its output circuit, and from its input to ground, which is included in this effective input capacitance. Obviously, these two stray capacitances should be kept as small as possible by proper physical design of the probe.

It may be seen that the combination of the series isolating resistor with the overall shunt input capacitance, also forms a low pass resistance-capacitance divider for AC potentials. When the frequency is fairly low, the capacitive reactance is fairly high, so that the isolating resistor does not drop very much applied AC voltage. When the frequency is higher, the capacitive reactance becomes fairly low, so that the isolating resistor drops practically all of any applied AC voltage. This provides sufficient high frequency attenuation to keep any strong high frequency components (such as RF) that may be present in the DC voltage under test from the metering circuit.

As shown above, the isolating resistor is in series with the resistors that form the voltage dividing network across the input. The resistance of the latter is 10 megohms in many commercial VTVMs. Consequently, a portion (about 10% in this case) of the applied DC voltage that is to be measured will appear as a voltage drop across the isolating resistor, and the remainder (about 90%) will be applied to the VTVM. This reduces the meter deflection produced for a given input test voltage. However, an isolation probe is supplied as standard equipment with most VTVMs and the meter is calibrated for use with this particular probe. No other probe should be used unless it is known to be of the same values. Any other probe will give false meter readings. The manufacturer's instruction book will give the value of probe and meter input resistance.

For the measurement of high frequency AC voltage, an additional probe that is called an RF PROBE may be utilized with a VTVM. In an RF probe, a diode is built directly into the probe. In this way, capacitive loading from the VTVM on the circuit under test is kept at a minimum; also, the VTVM is able to measure a higher frequency range since the output from the probe diode is DC voltage. Therefore, the capacitance of the cable and the VTVM input circuit has no reactive attenuating effect on the signal being measured.

In the training vehicle VTVM, a Crystal-Diode (RF) Probe may be used with the VTVM to extend the frequency range to 250 mc. This probe consists of a germanium rectifier and an R-C network in a polystyrene housing. The probe, which slips onto the front of the DC probe and cable, eliminates the need for an extra cable. The schematic diagram is shown below.

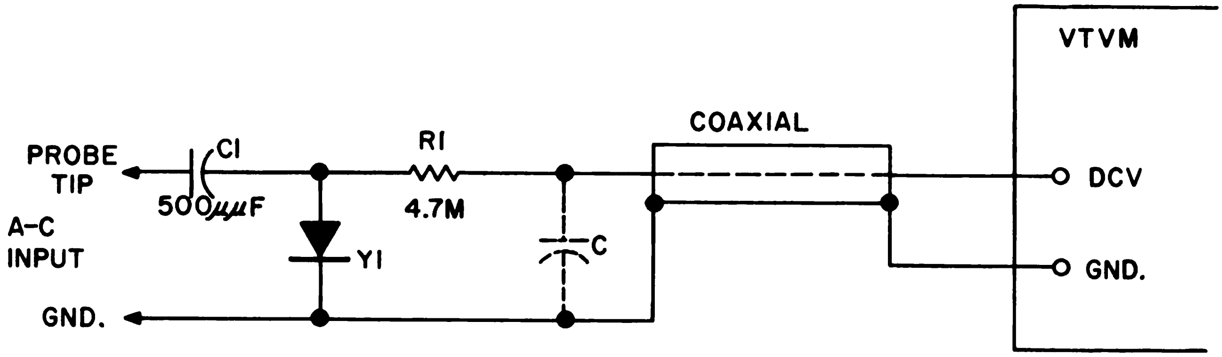
This RF probe may be used in RF circuits to measure sine-wave voltage values up to 20 rms volts in the presence of DC voltage as high as 250 volts. The overall frequency range of the probe is from 50 kc. to 250 mc. All RF voltages are read from the DC scales in terms of rms volts for sine waves. For example: A reading of 5 volts DC indicates that the sine wave being measured has an rms value of 5 volts. The overall accuracy of the WV-98C when used with the RF probe is ±10%. The operation of this probe is approximately the same as the rectifier for the AC VTVM covered earlier in this topic.

The VTVM, like the VOM, can also be used to measure voltages greater than those for which it was basically designed. This is done by means of a HIGH VOLTAGE PROBE. This probe is similar to the VOM HV Probe described earlier. Because of the higher average input resistance of the VTVM, a VTVM HV probe has considerably less loading effect on a high-resistance, high voltage circuit than does the VOM HV probe.

For a VTVM having a 10 megohm input resistance, the value of the series multiplier resistor, which is in the handle of the HV probe, is 1090 megohms for a 100:1 voltage reduction. The 1090 megohms adds to the 10 megohm input resistance of the VTVM, giving a voltage divider having 1100 megohms total input resistance. Computing the value of the HV probe is not quite as simple as it appears. The reason being that the VTVM scale is calibrated for a certain input resistance (say 11 Meg/V). If one volt is applied to DC probe only 10/11 of this appears across input voltage divider, yet meter reads one volt. A special formula is needed:

$R_p = R_c + (M - 1)R_{in}$ where Rp is the resistance of HV probe multiplier; Rc is the resistance of the DC isolation probe; M is a meter multiplying factor desired (100 in case where 500V. scale is to be used to measure 50,000V.); R_{in} is the input resistance of VTVM when DC probe is in place. Thus

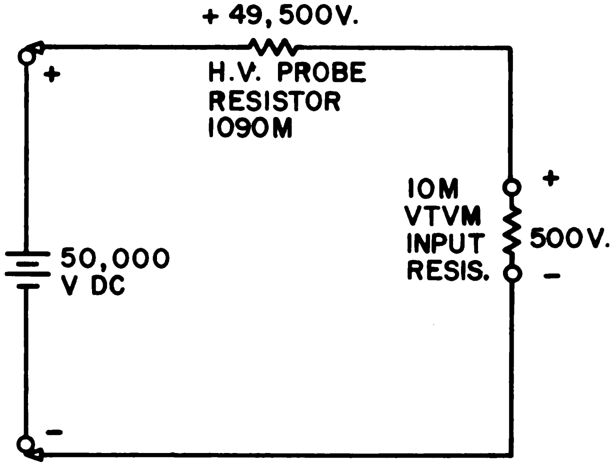
Rp = 1 Meg + (100-1) 11 Meg
Rp = 1 + (99) 11
Rp = 1 + 1089
Rp = 1090 Megs



22. VTVM RF PROBE

The input to the 10 megohm VTVM measuring circuit is 1/100 of the high voltage being measured. The probe may be used on any of the VTVM voltage ranges where the input resistance is 10 megohms.

The training vehicle HV probe may be used to measure DC voltages as high as 50,000 volts. With a multiplying factor of 100, the WV-98C provides six full scale positions of 150, 500, 1500, 5000, 15000, and 50000 volts. Do not measure voltages higher than 50,000 volts. because the maximum voltage rating of the probe may be exceeded. The extremely high impedance of the HV probe is especially desirable when it is necessary to measure voltages found in phototubes, geiger counter tubes, TV, and other high Z circuits which would not function properly if loaded down by a low Z voltmeter.



23. VTVM HV PROBE MEASURING 50,000 VOLTS

TRANSISTOR MULTIMETERS

Transistorized versions of the VTVM, or electronic multimeter, are now in use. These usually are called transistor voltmeters and are often designated TRVMs. Transistors offer the same advantages when used in an electronic measuring instrument as when used in any electronic equipment. These advantages include no warmup time; no need to plug into an AC outlet; reduced size and weight; practically no heat generated; and the potential advantage of greater stability.

Needless to say, these advantages are not obtained for free. Most of the disadvantages of transistors still apply. The only disadvantage that is of much concern however is the inherently low input impedance of most transistor configurations. This limitation is inherent in the fact that the transistor is a current actuated device in contrast to the vacuum tube which is essentially voltage operated. As a result, input impedance beyond one megohm are not readily obtainable with transistors, even in the common collector configuration.

One method for overcoming this limitation makes use of a vacuum tube operated as a cathode follower, followed by transistors, resulting in a hybrid (tube and transistor) instrument. We are, however, only concerned at this time with a fully transistorized type as an example.

A typical all transistor instrument is much like a VTVM in appearance, having a Function switch, a Range switch, a pair of Input jacks, and a meter calibrated for Resistance, DC Volts, DC microamperes and AC Volts. The main difference is that this instrument will measure very low values of current whereas most VTVMs do not even measure current directly. The actual current ranges in our typical model are 0 to 5, 0 to 50, 0 to 500, and 0 to 5000 microamperes. Additional ranges are available using accessory shunts. The need to replace the transistors is practically nonexistent, mainly because stable, long life transistors are used in circuits, and these are operated considerably below their maximum rated values.

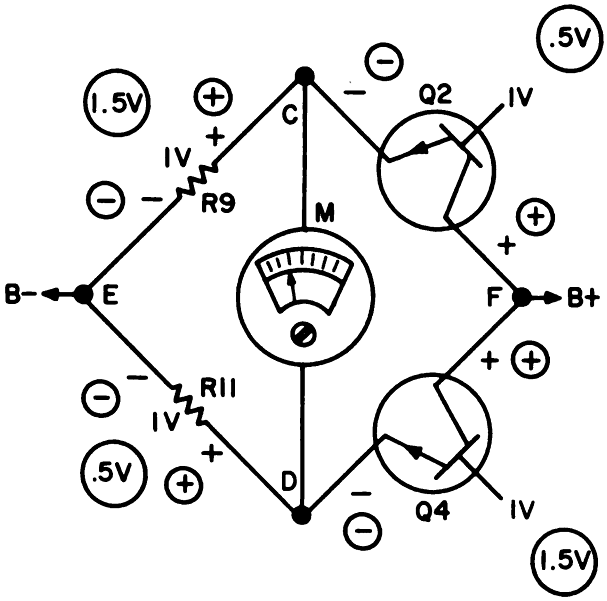
The DC voltage ranges are 0 to 1, 0 to 10, 0 to 100, and 0 to 1000 volts. The input resistance on the 0 to 1 volt range is 920K. This means that on that range the TRVM is a 920K ohm/volt meter. This is much better than any of the usual VOMs, but not as high as the 11 megohm/volt input of most VTVMs. On the 0 to 10 volt range, input is 1 megohm/ volt, which is maximum for this meter. On the higher voltage ranges where accuracy is of less relative importance, the input resistance drops to 100K ohms/volt on the 0 to 100 volt scale, and 10K ohms/volt on the 0 to 1000 volt scale. This variable range of input resistances is characteristic of TRVMs because they must draw proportionately different values of current from the circuit under test for the different scales because the transistors are current actuated devices.

The AC voltage ranges and input resistances for each are:
0 to 5 scale = 130,000 ohms/volt
0 to 50 scale = 36,000 ohms/volt
0 to 500 scale = 3,600 ohms/volt
0 to 5000 scale = 360 ohms/volt

Four resistance ranges are provided, the lowest is 0 to 10K ohms, and the highest is 0 to 10 megohms.

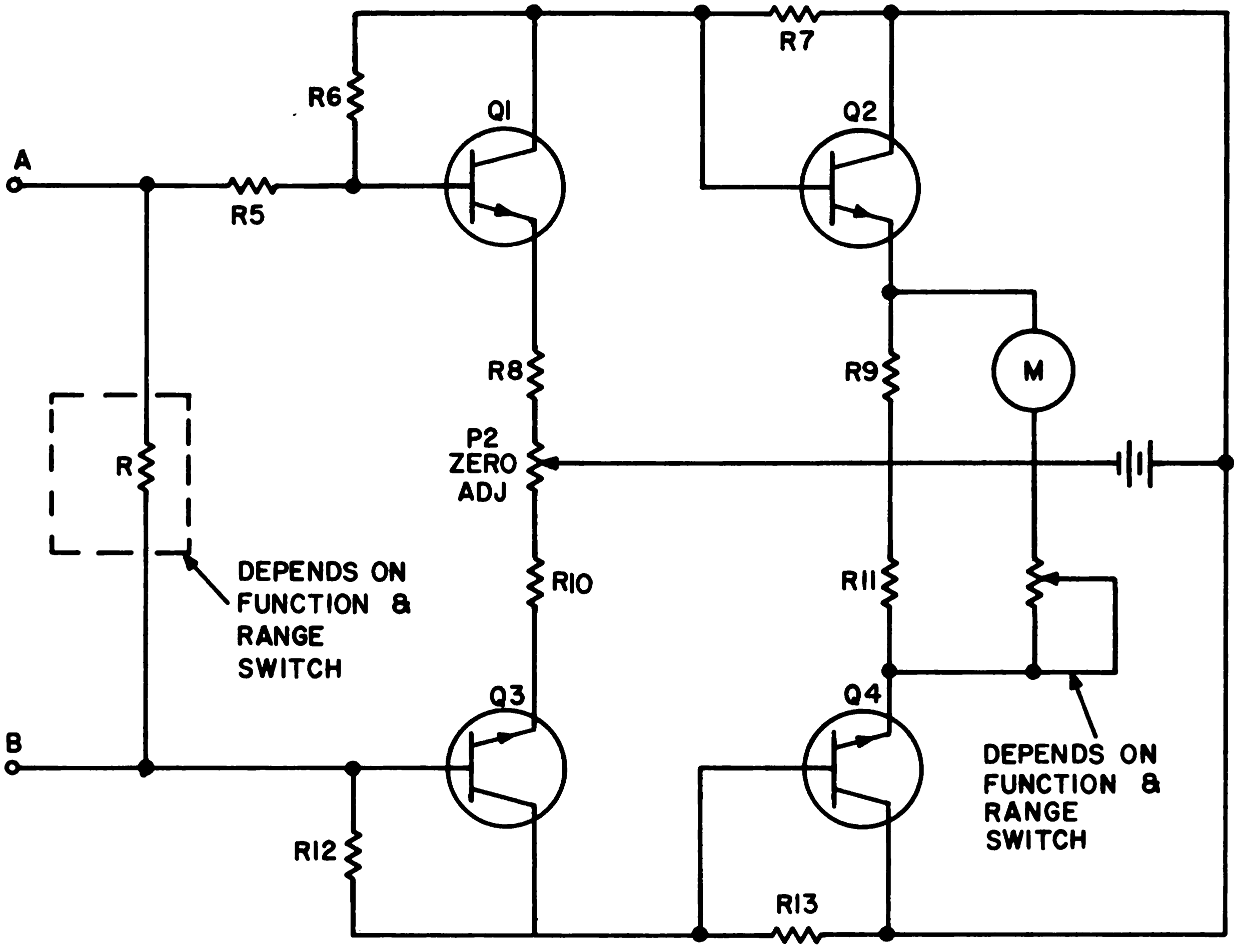
The frequency response is ±1 db for 10 cps to 500 kc. The sources of power are three size D cells for the amplifier circuit and one size C cell for the ohmmeter circuit. The simplified circuit of a TRVM is shown on facing page with just the basic components necessary to illustrate the principles of operation shown.

The function to be measured is applied to terminals A and B. Resistance R in the box is a substitute for all the switching functions and ranges for the various modes of operation. The signal applied to A-B and modified by R, varies the base emitter bias currents of Q1 and Q3, Q1 in the opposite direction from Q3. The varying bias will vary Q1-Q3 conduction through R7-R13 and thus change the bias on Q2-Q4. This will cause collector current in Q2-Q4 to vary proportionately to this change. Q2-Q4 varying currents will unbalance the meter bridge circuit because these two transistors are two legs of the bridge as shown in adjacent column.



24. TRVM METER BRIDGE CIRCUIT

Let us take one strictly hypothetical situation to explain the bridge action. With no input signal to the TRVM the bridge is balanced and the uncircled voltages (left) exist. Note that both points C and D are at the same potential and no current will flow through the meter. Now apply the test prods to an input signal that will vary Q1-Q3 conduction in such a fashion that collector current in Q2 will increase and in Q4 decrease. The results of this are the circled voltages (left). The increased current through R9 increases the voltage drop across it and the increased current through Q2 lowers its internal resistance and thus the voltage drop across it. Just the opposite effect takes place in R11-Q4 due to reduced current through that leg. Note now that there is a one volt potential across the meter from D to C. This will cause current to flow through the meter, giving an indication on the scale proportional to the current flow through the meter movement.


A
B
R5
R6
R7
Q1
Q2
R8
R9
M
P2
ZERO
ADJ
R
DEPENDS ON FUNCTION & RANGE SWITCH
R10
R11
DEPENDS ON FUNCTION & RANGE SWITCH
Q3
Q4
R12
R13

25. TRVM SIMPLIFIED SCHEMATIC

Experiments 2-2-1, Meter Loading Effect, Overdriven Amplifier

In this experiment you will compare the effect of a VOM and a VTVM on the overdriven amplifier circuit of the chassis.

With the circuit in a proper operating condition (square wave on the scope from plate pin 5 (A-11L) V3B) measure the voltage at grid pin 1 (A-10L) of V3A with a VOM on the 10 volt scale and observe the effect this has on the square wave presentation on the scope. There should be only a slight change. Next measure the same voltage with a VTVM and observe the presentation. There should be no change. Comparing the effect of the two meters you will find that, even though the VOM had some effect, it did not seriously affect the operation of this circuit. Therefore either meter could be used for taking measurements at this point.

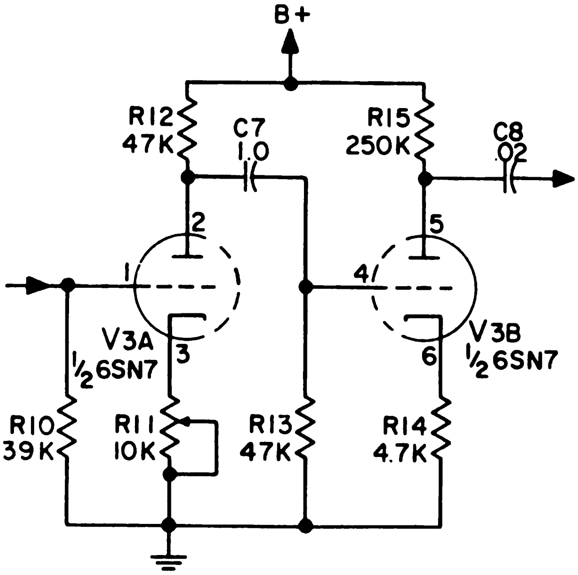
WARNING

> Do not reverse the test leads when measuring high voltages of different polarities. Use POLARITY REVERSE switch on the electronic voltmeter. Contact between the voltmeter case and ground may cause severe shock, if the above caution is not observed.

Experiments 2-2-2, Meter Loading Effect, Cathode Follower

In this experiment you will compare the effect of the VOM and the VTVM on the cathode follower circuit.

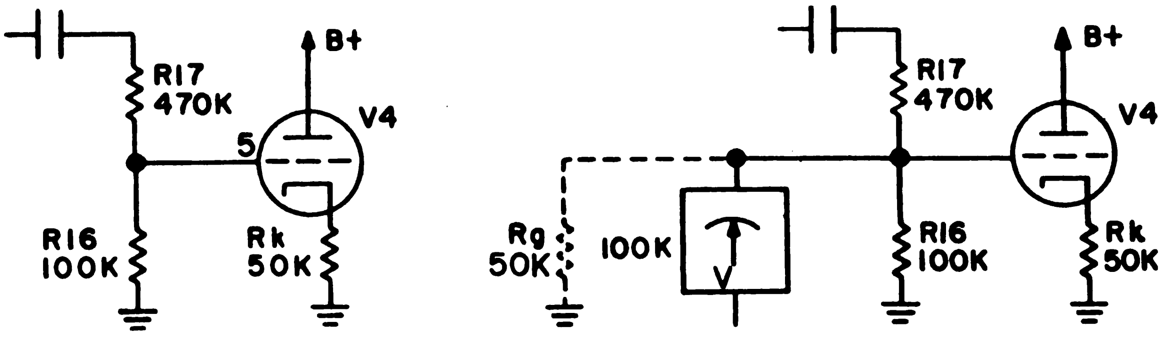
Connect the scope vertical input probe to the cathode pin 8 (A-19L) of V4 and adjust for a square wave presentation. Connect the VOM and VTVM negative leads to ground. Set both meters on the negative DC 5 volts scale. Touch the positive lead on the VOM to grid pin 5 (A-17L) of V4 and observe the effect this has on the scope presentation. It should decrease to about one half of it's original amplitude. Next touch the VTVM positive lead to the same point and observe the waveform. There should be no apparent effect; the difference in the effects of the VOM and VTVM in this circuit is so pronounced that it would be well to analyze the circuit to determine the reason.



26. SPECIAL CIRCUITS CHASSIS OVERDRIVEN AMPLIFIER

In the illustration at top of facing page, (A) shows the input circuit for the cathode follower. The signal from the plate of V3B is being developed across the voltage divider network R16 and R17. The voltage applied to the grid is the voltage developed from grid to ground across the 100K resistor R16 and is therefore, determined by the ratio of R16 to total resistance or 1:5.7. In the same illustration, (B) shows the same circuit with the addition of the VOM. Since the VOM on the 5 volt scale has an internal resistance of 100K (5 x 20,000), Rg from the grid to ground has decreased to 50K. The ratio of Rg to Rt is now 1:10.4. Therefore, more of the signal will be dropped across R17 and less across the circuit from grid to ground. When the VTVM is connected into this circuit, it's internal resistance is so high (11 megohms in most VTVMs) that it's effect on the total resistance from grid to ground is negligible. Therefore, the signal applied to the grid will be affected so little that is unnoticeable with most test equipment.

Next set both meters on the positive 25 volt DC scale and check the voltage from cathode pin 8 (A-19L) to ground while you observe the effect on the scope. In this case, the input impedance of both meters is much higher (VOM 500K-VTVM 11 MEGOHMS), than the circuit impedance at this point (about 4.7K), therefore, neither meter will affect the circuit noticeably.



(A)

(B)

27. VOM EFFECTS

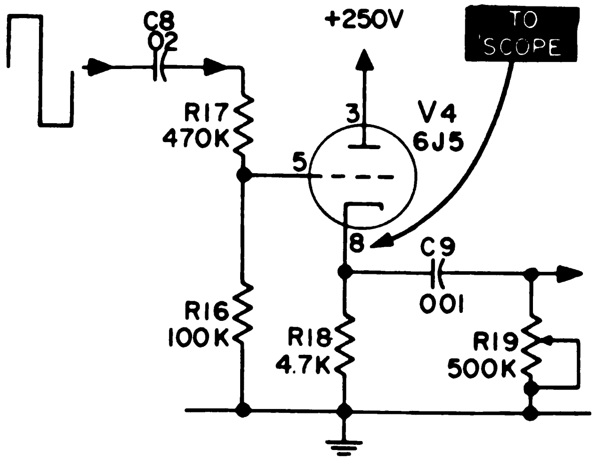
Experiments 2-2-3, Meter Loading Effect, Differentiator

In this experiment you will compare the effects of the VOM and the VTVM on the differentiating circuit C9 and R19 at different settings of the potentiometer R19.

Set both meters on the 5 volt DC scale and connect the negative leads to ground. With R19 set at 125K and the circuit in operation, touch the positive lead of the VOM to the top of R19 (A-20L) and observe the effect on the waveform presentation on the scope. There should be considerable change in the waveform in both amplitude and the amount of differentiation. By this time you should be able to analyze the circuit involved and explain the reason for the occurance. Next touch the positive lead of the VTVM to the top of R19 (A-20L) and observe the results on the scope. There should be no change.

With R19 set on 50K, repeat the experiment with both meters. The VOM should have somewhat less effect here than it did with R19 set at 125K, due to the lower circuit impedance. The VTVM will still have no effect.

It should be evident from this experiment that placing a VOM on the 5 volt DC scale across the differentiated output could seriously affect the circuits that are being triggered by this output since both the amplitude and the width of the spike are affected.



28. DIFFERENTIATOR

Experiments 2-2-4, Meter Loading Effect, Limiter

In this experiment you will see how a VOM, used under certain conditions, can give a false impression of a casualty.

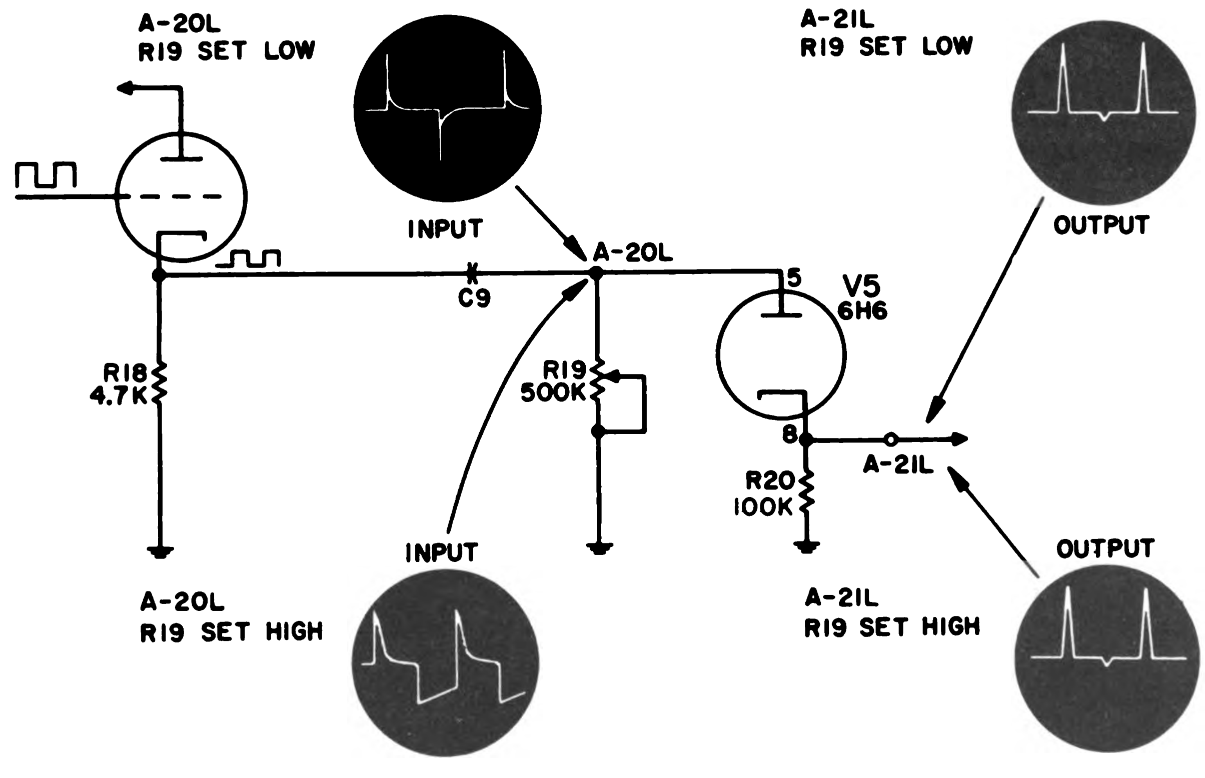
For this experiment set up the V5 circuit as a series negative limiter. Connect the scope's vertical probe to the cathode pin 8 (A-21L) limiter. Observe that the negative portion of the waveform is being limited. Note the amplitude of the waveform.

Deenergize the chassis and unsolder the ground end of R20 (A-21R). This opens the circuit and there should be no output. Apply power to the chassis and observe the waveform on the scope. With the scope connected across this open circuit you should observe very small negative and positive spikes.

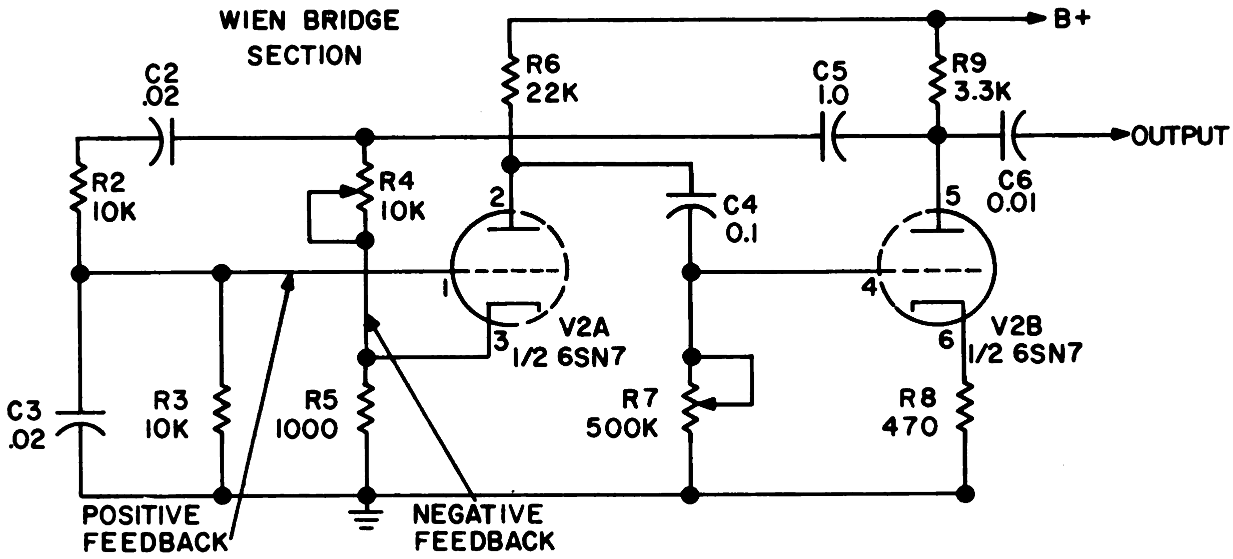
With the positive lead of the VOM connected to the cathode pin 8 (A-21L) and the negative lead connected to ground, select the DC voltage scale which presents a meter reading closest to, but does not exceed, full scale deflection. The meter will measure approximately 5 VDC. When selecting the proper DC voltage scale on the meter start with higher scales and select lower scale when it is known to be safe for the meter. Observe the waveform on the scope. The amplitude and limiting action should be the same as it was with R20 connected into the circuit, since the internal resistance of the meter on the 5 volt scale is the same value as R20 or 100K. From all indications, the circuit seems to be operating properly except that the VOM reads a slight amount higher than normal. In reality, R20 is open and we have a signal due to the insertion of the VOM into the circuit. Next place a VTVM on the 5V scale between pin 8 of V5 and ground and observe the effect on the presentation on the scope.

It can be seen from this experiment that the unskilled technician, unaware of the VOM limitations could easily run into difficulty in trying to diagnose this type of casualty.

Deenergize the chassis and resolder the ground end of R20 to it's terminal (A-21R).



29. SERIES NEGATIVE LIMITER



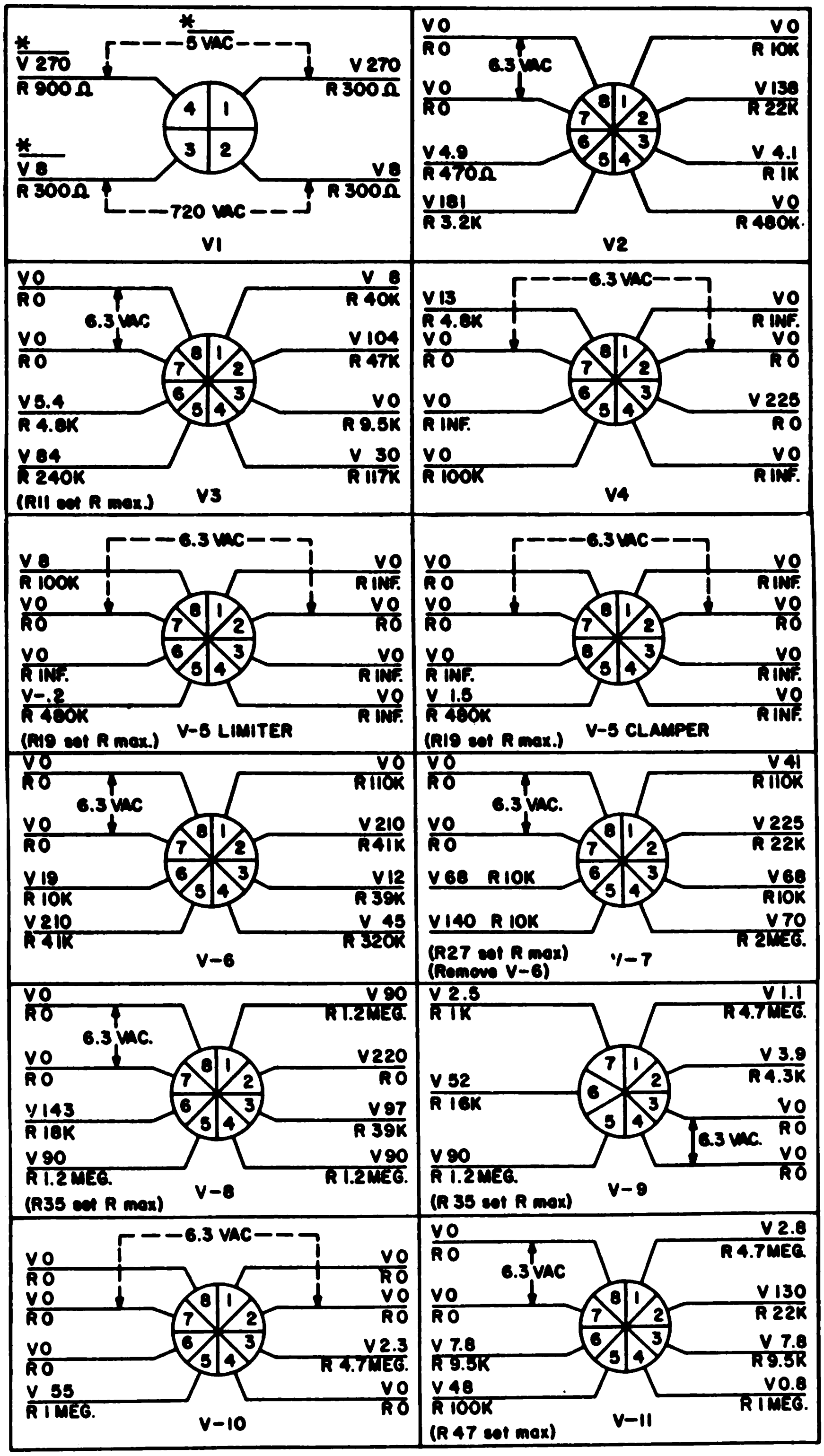
30. WIEN BRIDGE OSCILLATOR

Experiments 2-2-5, Application of Basic Test Probe

Earlier you saw how the VOM loaded down certain circuits. In this experiment you will see how the loading effects of test equipment on a sensitive circuit can be reduced to an acceptable level.

Connect a scope to the plate pin 5 of V2B and adjust for a steady waveform. Now touch the direct probe of the VOM to the grid pin 1 of V2A and observe the effect on the scope. Next clip a 4.7 megohm resistor to the probe tip and touch this to the same point. You should notice very little effect on the scope presentation. The 4.7 megohm resistor is acting as an isolation probe for the meter, reducing the loading effect on the Wien Bridge Oscillator.

Since the VOM is calibrated for use with a direct probe, the 4.7 megohm isolating resistor has reduced the meter reading to a very low value, as most of the voltage is dropped across the isolation resistor. Although it is possible to calculate a multiplication factor by which the voltage could be determined, it is much more practical and accurate to use a VTVM with the standard isolation probe.



31. CHASSIS VOLTAGE AND RESISTANCE DIAGRAM

Experiments 2-2-6, Voltage and Resistance Measurements

When troubleshooting vacuum tube circuits, best results are attained by following certain definite steps. They are (1) isolating the trouble to the defective stage by signal tracing, (2) tube checking, (3) voltage checking tube pins to determine defective circuit, and (4) resistance checking defective circuit to isolate defective components.

In order to check for proper voltage and resistance, references are needed. These are voltage and resistance diagrams provided in NAVWEPS OPs for equipments. The voltage and resistance diagrams show a drawing of each tube socket, the voltage and resistance of each socket pin. These values are taken under set conditions and these conditions under which the readings are to be taken are listed on the diagram.

Following is a voltage and resistance chart of your Fire Control Radar Special Circuits Chassis. Take two readings on your chassis and compare them to the readings on the chart. (Read the notes on the voltage and resistance diagram before taking readings.)

Some variation is allowed due to the tolerance of the components and variations in the power supply output.

NOTES:

1. Voltages DC to ground unless otherwise stated.
2. Voltages read with a 20,000 ohms-per-volt meter.
3. Voltages read with circuit in operation.
4. Resistance read with potentiometers set at maximum resistance, B+ terminal grounded and power off.

Experiments 2-2-7, Measuring High Voltage

One of the accessories of the VOM that was pointed out by the instructor when discussing the AN/PSM-4 was the high voltage probe. This probe extends the range of the AN/PSM-4 to 5000 VDC.

Many times during corrective maintenance you will find it necessary to measure high voltages. It is the purpose of this experiment to provide you with this skill.

You are familiar with safety precautions for electrical work. They apply to this experiment. Before you perform this experiment, your instructor will demonstrate the correct procedure to be followed. Be alert! If you observe all precautions, measurement of high voltages is a simple and safe task.

Materials needed:

1. A AN/USM-117 Oscilloscope and power cord.
2. A AN/PSM-4 Multimeter (VOM) and accessories.
3. A medium sized screwdriver, 10", plastic handled with rubber sleeve grip.

Preliminary preparations:

1. If already attached, disconnect the power cord from the scope.
2. Set the scope ON-OFF switch to OFF.
3. At the rear of the scope case there is a slotted head fastener. Turn this 1/2 CCW turn; the scope is free of its case.
4. Use one hand to hold the case by its carrying handle. With the other hand, pull the scope out of its case.
5. Place the scope on your wooden bench top, making sure that the immediate area about the chassis is clear.
6. Connect the power cord to the scope.
7. Close to the face of the CRT at one side, you will find a red lead connected to the CRT through a molded rubber plug. The lead is encased in a clear sheath. Trace the red lead

to its other end, a terminal lug. It is at this lug that you will measure 2400 VDC.

NOTE: At this time there is no power to the scope.

Once the preliminary preparations are complete, check to make sure that the chassis is still clear of loose gear. Having checked, proceed to the actual measurement.

CAUTION

Do not deviate from the following sequence. You may harm yourself or the equipment or both.

1. Set the AN/PSM-4 alongside the scope face up.
2. Use the black lead with alligator clip for ground. At the scope a BNC's outer conductor makes a good ground.
3. Screw the high voltage probe into its jack at the VOM.
4. Clip the probe jaws to the terminal lug under test.
5. Plug the scope power cord into a receptacle. Make sure that the plug grounding prong is connected.
6. Turn the scope power on, stand clear of the test set-up.
7. You should note the following:
   a. Scope pilot light lit.
   b. A faint high frequency howl from the scope.
   c. Meter needle deflected to 24 on the 50 volt DC scale.
   d. Glow lamp in the probe body is lit.

WARNING

At no time while the 2400 volts is being measured should you touch the meter, probe, or scope.

When the measurement is completed:

1. Turn off scope power.
2. Unplug power cord at scope and receptacle.
3. After one minute, use the screwdriver to discharge the terminal lug.
4. At the scope, disconnect the probe, then the ground lead.
5. Stow the AN/PSM-4 and accessories.
6. Stow the AN/USM-117 scope by reversing the order of the preliminary preparations.

Review and Summary

In this topic you learned about multimeters and vacuum tube voltmeters. Both are in wide use for circuit measurements of voltage and resistance. The multimeter is also used for current measurement.

The multimeter is extremely handy since it is easily portable, requiring no external power source and is highly accurate in most cases. The AN/PSM-4 series, in wide use throughout the Navy has a 50 μ amp meter movement and a 20,000 ohms per volt sensitivity on the DC ranges. The main disadvantage of the multimeter is that current must be drawn from the circuit under test to operate the meter movement. This results in circuit loading when the lower ranges are used to measure voltages of high impedance circuits. The accuracy of the multimeter is affected by frequency on AC and OUTPUT scales.

The VTVM has a constant high impedance input for all ranges, resulting in negligible circuit loading. Most VTVMs require an external power source but a few use batteries. This source supplies current for the meter movement, the circuit under test need only supply a voltage to the control grid of the VTVM amplifier tube. The VTVM is supplied with a high impedance probe and shielded test lead which, with the high input impedance of the meter, make it suitable for accurate voltage measurements on nearly any circuit within its designed range of voltage and frequency.

Some of the special test probes you will use with multimeters were also discussed.

These included the DC Isolation Probe, the RF Probe, and the High Voltage Probe. By using the proper test probes at the proper time with test equipment you will greatly increase the usefulness of the test equipment.

TOPIC 3: C, L, AND R BRIDGE ZM-11/U

You Are Now Going to Learn:

1. The principle uses of the ZM-11/U.
2. The theory of operation of the ZM-11/U.

You Will Acquire Skill in:

1. Measuring resistance with the ZM-11/U.
2. Measuring capacitance with the ZM-11/U.

Discussion Points for this Topic Are:

1. Introduction.
2. Operation.
3. Experiments.
4. Review and summary.

INFORMATION AND DISCUSSION:

INTRODUCTION

The ZM-11/U is a precision test instrument for shipboard use. It is used to measure capacitance, inductance, resistance, transformer turns ratios, dissipation factor of inductors and capacitors, and leakage in electrolytic capacitors.

You will use the ZM-11/U to measure resistance and capacitance in the experiments to follow. You will attain skill in its operation and knowledge of its usage.

Some fire control electronic equipment contains circuits having precision resistors and capacitors with extremely close tolerances. These circuits usually have very critical output characteristics for proper operation. The ZM-11/U can be used to check these circuit components accurately.

OPERATION

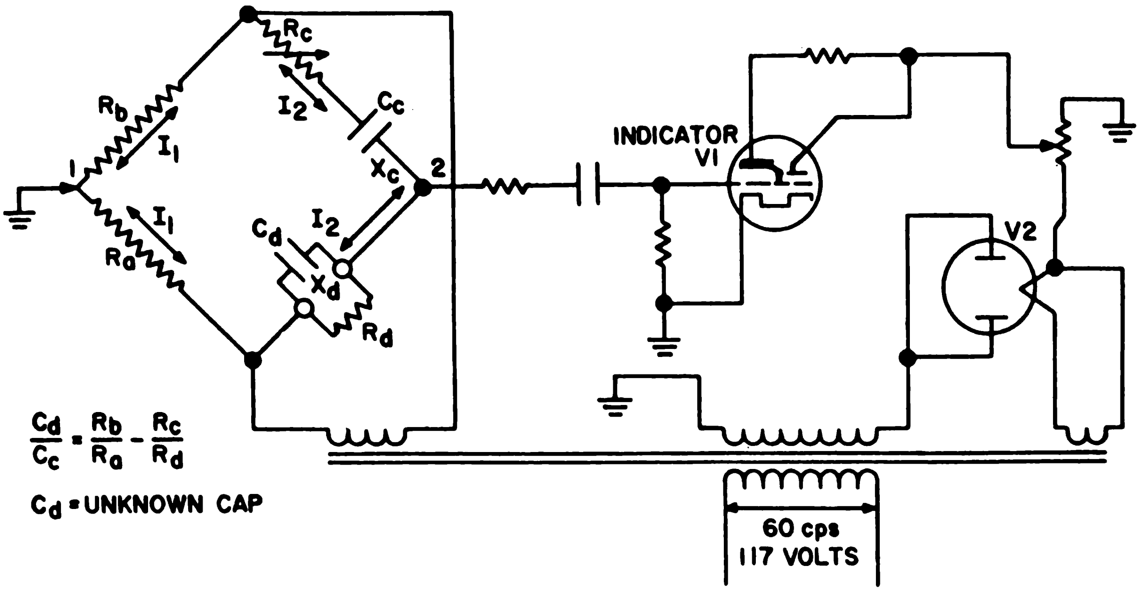
Capacitance, inductance and resistance are measured for precision accuracy by means of alternating current bridges which are composed of capacitors, inductors, and resistors in a wide variety of combinations. These bridges operate on the same principles as the wheatstone bridge (resistance bridge). That is, an unknown resistance is calculated in terms of the known resistance after the bridge has been balanced.

On the facing page at bottom is shown a simplified capacitance bridge circuit. Indicator tube, V1, is an electron-ray tube. Conduction of V1A controls conduction of V1B, whose plate is a fluorescent screen. Heavy conduction of V1B results in a circle of green light (cat's eye) while little conduction produces a shadow.

When the bridge is balanced by adjustment of two variable resistors (dials indicate capacitance) there is no AC voltage developed across the input of indicator tube (V1), and it's shadow angle is maximum. Any slight unbalance produces an AC voltage which in turn develops a grid leak bias and lowers the Ip of V1, thus reducing the shadow angle.

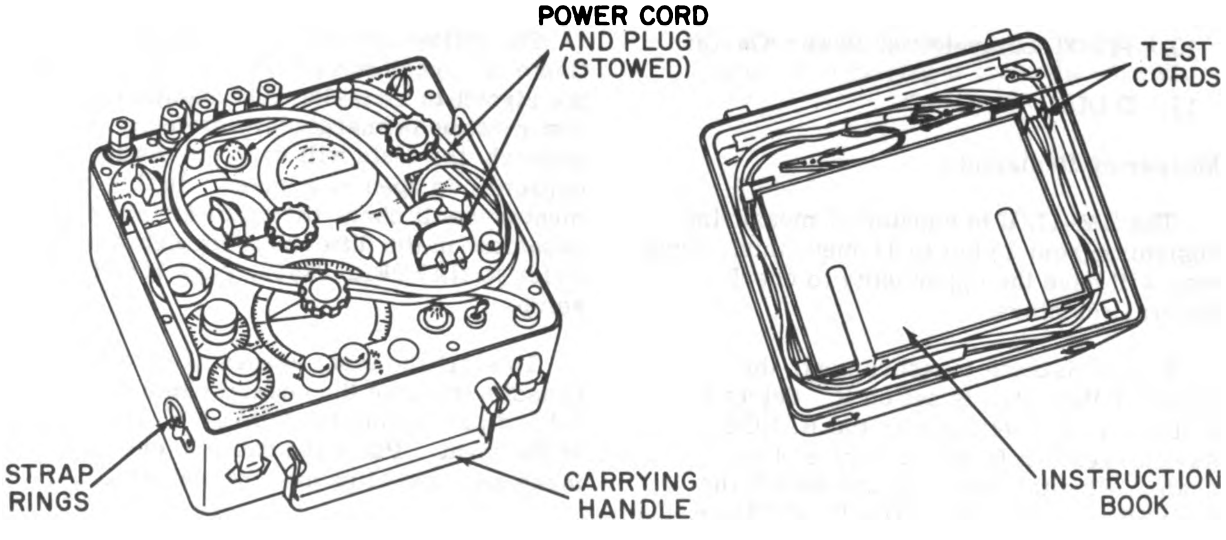
Capacitors may be checked either in the circuit or disconnected from the circuit. Electrolytic capacitors may be polarized and charged to the rated voltage to check for leakage current. Complete instructions are contained in Instruction Book, NAVSHIPS 91704.

When using normal troubleshooting methods, a suspected open capacitor can be checked by touching a known good capacitor across it's terminals. A shorted capacitor can easily be found with an ohmmeter. The advantage of the ZM-11/U is it's ability to



32. SIMPLIFIED SCHEMATIC OF CAPACITY CHECKER

check marginal components, ones that have changed values but are not open or shorted. For instance a capacitor that has changed in value is very difficult to find by normal methods, yet it is often impractical to replace all suspected capacitors in the circuit. This is only one case in which the ZM-11/U can be used to good advantage.



33. CAPACITANCE, INDUCTANCE, AND RESISTANCE BRIDGE ZM-11/U

Experiments 2-3-1, Checking Resistors and Capacitors

In this experiment you will have an opportunity to gain experience in using the ZM-11/U and learn a few of the test functions it is able to perform. Before beginning the experiment, remove the cover from the ZM-11/U and locate the following switches and dials you will use in this experiment.

1. FUNCTION Switch-upper left.
2. RANGE Switch-upper left.
3. BALANCE-Indicator-center left.
4. MULTIPLY RANGE by Dial-lower center.
5. PANEL METER-upper center.
6. VOLTAGE CONTROL-upper right.
7. OSCILLATOR ADJUST-to right of Panel Meter.
8. OSCILLATOR Switch-right center.
9. POWER-ON-OFF-lower right.
10. PILOT Lamp-left of Power-On-Off.
11. D DIAL-lower left.

Measuring Resistance

The ZM-11/U is capable of measuring resistors from 1 ohm to 11 megohms. Each man will have the opportunity to check several resistors.

For resistance measurement, the FUNCTION switch is set on R. Select a suitable range setting with the RANGE switch, reading from the R ring of the scale. Plug the meter in and switch the POWER switch to ON. The PILOT lamp should light up and after a few minutes warm up time, the BALANCE indicator should glow a light green. Connect the unknown resistor to the R posts, second and fourth from the left at the top of the meter. Adjust the MULTIPLY BY dial until the BALANCE indicator pattern shows the maximum possible opening in the eye, indicating balance. Multiply the RANGE switch setting by the MULTIPLY BY dial reading and you have the resistance of the resistor. Check several resistors in this manner.

Measuring Capacitance

The ZM-11/U is capable of measuring capacitances from 10 uuf to 1100 uf. You will need several different size capacitors to perform this experiment. Set up the meter in the following manner. Turn the FUNCTION switch to C. Select a suitable range for the capacitor under test with the RANGE switch, reading on the C scale. Energize the meter and allow warm up time (BALANCE indicator lights up). Connect the unknown capacitor between the C posts, third and fourth from the left. Attempt a balance (maximum opening of eye of the BALANCE indicator) by adjusting the MULTIPLY BY dial, perfecting it by simultaneous adjustment of the D dial. When balance is complete, multiply the MULTIPLY BY dial reading by the RANGE switch setting to obtain the capacitance. Perform this experiment with several capacitors.

Experiments 2-3-2, Capacitor Quality Tests

The following tests determine the condition of a capacitor without removing it from the circuit or chassis. The equipment under test must be deenergized, however. In general, the tests will determine whether a capacitor is open or shorted. In this experiment you will check the condition of C9, the capacitor in the differentiating network. Refer to NAVPERS 93582, page 166, for test setup.

To start the test, deenergize training chassis, remove the coaxial cable from the lid and plug it into the QUALITY TEST jack at the right. Place the cable to one side and make sure the clips are not touching.

To test for an OPEN, set up the meters as follows:

FUNCTION switch to CAP. QUAL.

RANGE switch to CAP. QUAL.

D dial to 0.

VOLTAGE control to 0.

OSCILLATOR switch to SET METER.

Advance the VOLTAGE CONTROL until the PANEL METER reads full scale. Then proceed as follows:

Turn OSCILLATOR switch to OPEN.

Set OSCILLATOR ADJUST until PANEL METER reads full scale. Now the meter is calibrated and the clips may be connected to C9, the capacitor to be tested. Connect the ground lead to the cable to the side of the capacitor nearest ground, in this case pin 8 of V4 (A-19L). Connect the positive lead of the cable to the other side of the capacitor (A-20L). If the PANEL METER continues to read full scale the capacitor is open. If the PANEL METER reads anything less than full scale the capacitor is not open and you may proceed with the SHORT test. Turn the OSCILLATOR switch to SHORT and again observe the PANEL METER. If it reads full scale, the capacitor is shorted. If it reads anything less than full scale, the capacitor is not shorted.

This test may be used for quick checks of many capacitors without disconnecting each one for testing. When the quality test indicates an abnormality, one end of the capacitor should be disconnected and the capacitor checked for capacitance in the usual manner.

The capacitor quality test of C9 can be considered as a true open and short test since C9 has a large resistor on each side of it. The test does have limitations however, since many capacitors are shunted by low resistances, such as in a high frequency tank circuit. This would give a false indication since the ZM-11/U operates at only 1000 cps and the coil impedance would be low.

Review and Summary

In this topic you have studied the use of the ZM-11/U Bridge and also performed experiments using it as the test instrument.

The principle points and uses you should have learned are listed below.

1. The operating principle of the capacitance bridge. When measuring the values of a capacitor, the variable capacitance dials are adjusted for balance at maximum shadow angle of the indicator tube. The value is read from these calibrated dials.

2. How to measure values of resistance with the resistance bridge.

3. How to measure values of capacitance.

4. How to make a capacitor quality test for a short and open in a capacitor without removing it from the circuit.

QUIZ SHEETS:

Answer the following questions. If necessary refer to the OP, the OD, or to the equipment.

1. What electrical quantity causes deflection of the needle in a multimeter?

2. What is done to a microammeter to enable it to read more values of current?

3. How is the microammeter changed to make it a voltmeter?

4. How is the sensitivity of a voltmeter determined?

5. Describe an ohmmeter.

6. What is done to a DC voltmeter to enable it to read AC voltage?

7. What is the internal resistance of a 100,000 ohms/volt meter on the 5 volt range?

8. Describe the steps to take in the use of the high voltage probe with the PSM-4D.

9. Why is it necessary to check the FUNCTION setting before taking a reading with a multimeter?

10. What is meter parallax?

11. What is the primary advantage of the VTVM over the VOM? Why?

12. What are the two primary functions of the VTVM's DC Probe?

13. Could the value of the resistor in the DC Probe of a particular VTVM be changed? Why?

14. Why is an RF Probe sometimes used with a VTVM?

15. In experiment 2-2-6, why was the B+ terminal grounded before taking resistance readings?

16. Why don't most VTVMs have direct reading current capabilities?

17. What similarity is there between the basic measuring circuits of the VTVM and the ZM-11/U?

Section 3

OSCILLOSCOPES

Topic No.	Topic Title	Page
1.	Cathode Ray Tubes	46
2.	General Purpose Oscilloscope OS-8E/U	52
3.	Synchroscope AN/USM-32.	72
4.	Synchroscope AN/USM-117	80
5.	Oscilloscope, Tektronix 545A	96

TOPIC 1: CATHODE RAY TUBES

You Are Now Going to Learn:

1. The construction and uses of the cathode ray tube (CRT).
2. The importance of the CRT.
3. The principles of electrostatic deflection.
4. Operation of the CRT.

Discussion Points for this Topic Are:

1. Introduction.
2. General construction.
3. Internal construction.
4. Electrostatic deflection
   a. Horizontal
   b. Vertical
5. Combined deflection.
6. Review and summary.

INFORMATION AND DISCUSSION:

INTRODUCTION

The information presented here is general in nature and does not pertain to a specific piece of equipment. Different CRTs will vary somewhat in contruction, but the theory of operation is fundamentally the same for all of a given type.

The CRT is the heart of the very versatile piece of electronic test equipment called the oscilloscope. You are studying the CRT so that you will better understand how it is used in the oscilloscope.

A second, equally important, use of the CRT is as an indicator in Fire Control Radars. Most of the circuits for the CRT used as an oscilloscope are similar to those when it is used in a radar. A complete understanding of this topic and those remaining in this Trainee's Guide will be a good preparation for the work to follow in radar.

GENERAL CONSTRUCTION

There are two basic types of CRTs. The first is the electrostatic (voltage) deflection type. This type is used primarily in oscilloscopes and radar indicators. It is the type we will be studying in this topic.

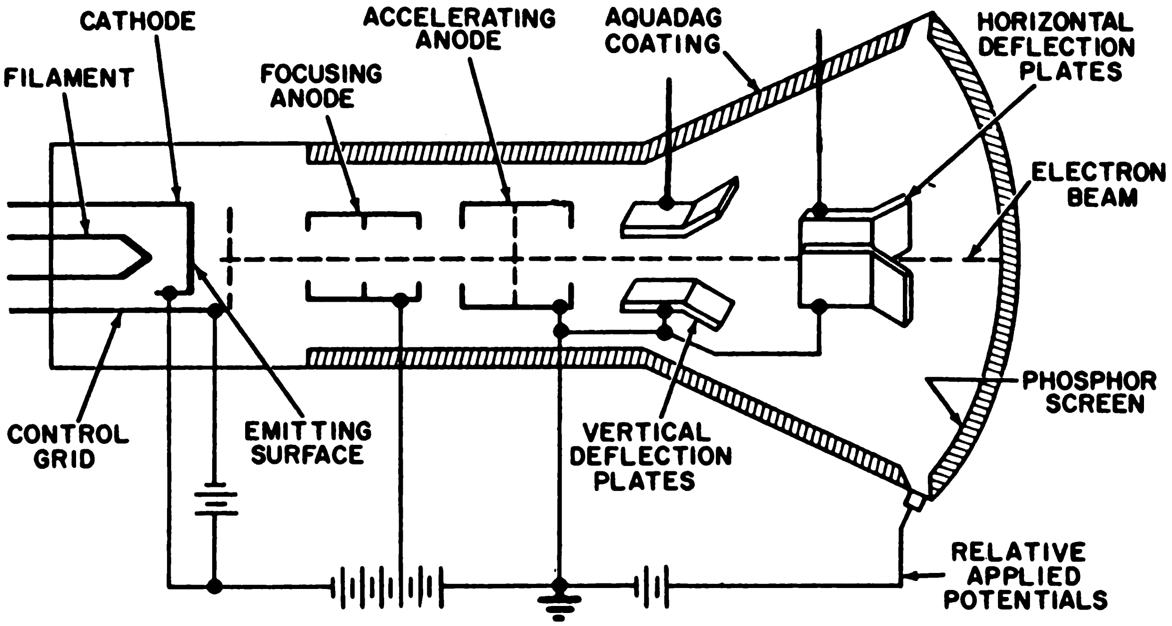
The second type is the electromagnetic (current) deflection type. Its primary use is in television but it also has some application in radar. These you will study later in the section on Radar Principles.

At the top of the facing page is a picture of a typical electrostatic CRT. Almost all CRTs are built along these general lines. A tapering bell terminating in a neck. The entire assembly is almost always made of glass. Sometimes the socket section at the end of the neck is made of plastic-like material. The size of the CRT is determined by the diameter of its face and ranges upward from one inch depending on the application the tube will be used in.

INTERNAL CONSTRUCTION

The internal construction of a CRT is shown above. It consists of the following components.

1. The electron gun is so named because it shoots a stream of electrons at the screen. It consists of the filament, cathode, control grid, first or focusing anode, and second or accelerating anode in that order from left to right. Sometimes there is a screen or accelerating grid between the control grid and the first anode.
2. The filament is used to heat the cathode and is powered by AC from a filament transformer.
3. The cathode emits (gives off) electrons when it is heated. It is the source of the electron stream, and is cylindrical in shape with a small electron-emitting surface to produce a very fine electron stream.



34. ELECTROSTATIC CATHODE RAY TUBE

4. The control grid is also cylindrical in shape. It regulates the number of electrons which flow past it from the cathode toward the screen. This control is obtained by varying the applied grid to cathode potential.

5. The focusing (or first) anode controls the size (diameter) of the electron beam as it flows past this area toward the screen. Control is obtained by varying the potential applied to this anode.

6. The accelerating (or second) anode raises the velocity of the electrons as they travel toward the screen. Acceleration is obtained by making this anode much more positive than the cathode.

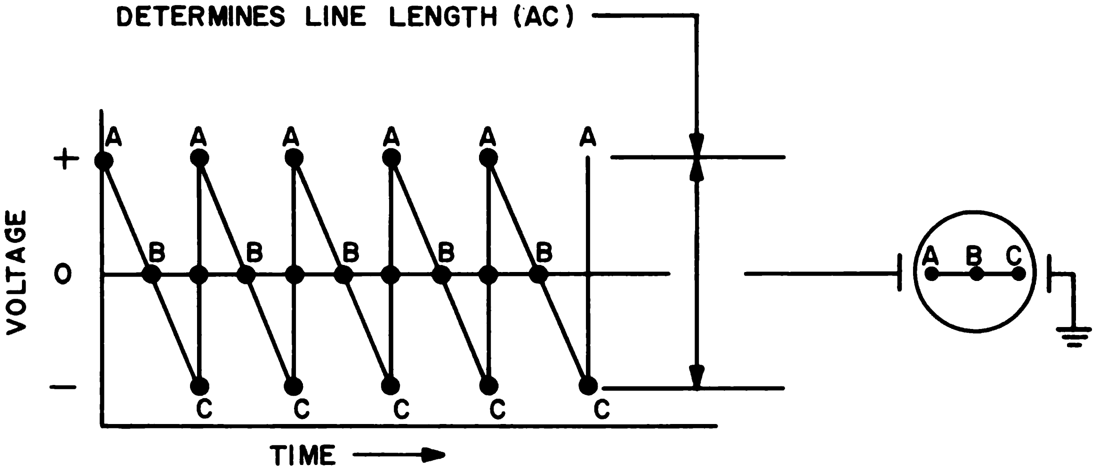
7. The deflection plates deflect the electron beam so that the beam can be caused to strike the screen at any desired spot. There are two pairs of plates. The left pair controls vertical movement and the right pair control horizontal movement. Deflection is obtained by applying voltages to the plates.

8. The display screen is a phosphor coating on the inside face of the CRT screen which glows when struck by the electron beam. This phosphor coating has a certain amount of persistency, that is, the glow will remain on the face of the screen for a short time after being struck. The glow will fade rapidly if the beam is cut off or moved to another location on the screen. After the electrons have struck the screen, they are collected by the positive aquadag coating painted on the inside walls of the tube, and returned to the power supply.

ELECTROSTATIC DEFLECTION

From the study of electrostatic charges created by friction you learned that "like" charges repel each other and that "unlike" charges attract. Since electrons have a negative charge it follows that the electron beam in the CRT will have a negative potential. Any negative voltage which is applied to a deflection plate will repel the electrons away from that plate. Any positive voltage applied to a plate will attract electrons toward that plate. With these basic fundamentals in mind we can discuss the action of the horizontal and vertical deflection plates in an electrostatic cathode ray tube.

HORIZONTAL — If there is no difference of potential between the horizontal deflection plates, the electron beam will flow exactly between them. No vertical deflection is assumed for this discussion of horizontal deflection. The path of the electron beam then will coincide with the centerline of the CRT



35. HORIZONTAL SWEEP GENERATION

and the electron beam will strike the center of the display screen.

For the discussion that follows, no difference of potential between the plates will be understood to mean that each plate is at the same potential (usually ground).

If the left plate is made positive with respect to the right plate the electron beam will be attracted toward the left and will strike the screen on the left hand side. The amount of deflection will be proportional to the amplitude of the potential applied to the plates.

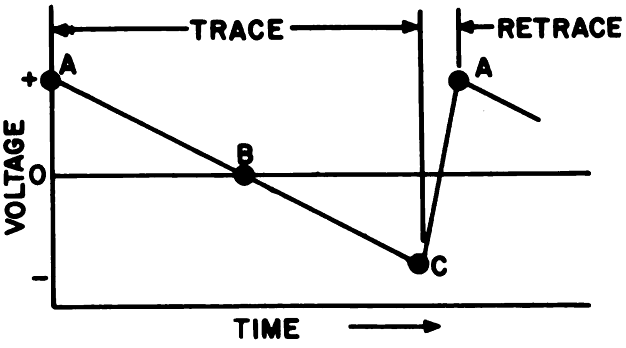
If a voltage waveform, such as that shown at the top of this page, is applied to the left hand plate, the electron beam will first be attracted strongly towards the left plate (Point A). As the voltage becomes less positive, the beam will be attracted less and less until the voltage reaches zero. At this time, the beam will be positioned exactly midway between the plates (Point B).

As the voltage continues to change, now in a negative direction, the electron beam will now be repelled from the left plate toward the right.

When the voltage has reached its maximum negative point, the electron beam will have reached its maximum excursion toward the right plate (Point C). Thus the beam will have traveled from the left hand side of the screen to the right hand side. Due to the persistency of the phosphor coating, the screen will glow in a straight line for a short time.

The voltage, having changed from maximum positive to maximum negative (A to C) will now repeat this sequence. It is seen above that this occurs after an instantaneous change (C to A) in potential. C to A causes the beam to sweep rapidly from right to left. The entire process is repeated over and over again as long as the waveform is applied.

This voltage waveform is known as a sawtooth. The foregoing discussion illustrated horizontal deflection of a specific type. It is referred to as HORIZONTAL SWEEP or TIME BASE. Briefly, the reason is this, The sawtooth is composed of straight lines and, as in every other waveform, its magnitudes (peaks) are plotted against time. Since time is a linear quantity, then this sawtooth may be used to "generate" time (it is an analog voltage). You will see this again in detail later as oscilloscope circuitry is discussed.



36. COMPONENT PARTS OF SWEEP SAWTOOTH WAVEFORM

As shown on the facing page, the electron beam traced a line from left to right and then returned instantaneously to start another cycle. Actually the return from C to A requires a small amount of time.

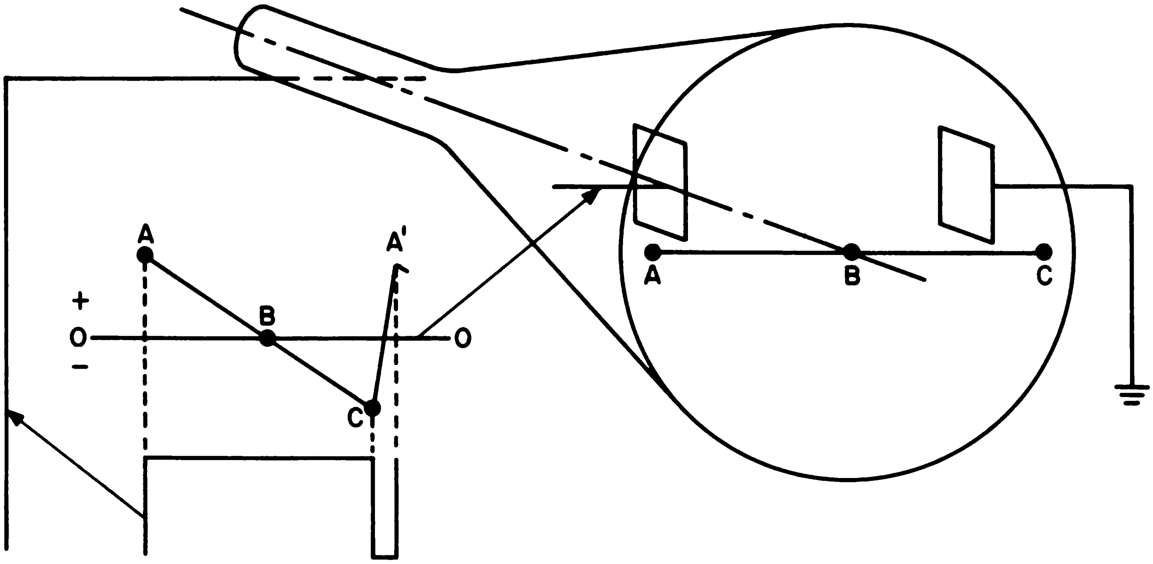
In the illustration above, one cycle of the sawtooth is expanded to show trace or sweep time, and retrace or flyback time.

Because there is actually some time consumed by the retrace, we will discuss at this time another waveform which is used during retrace time.

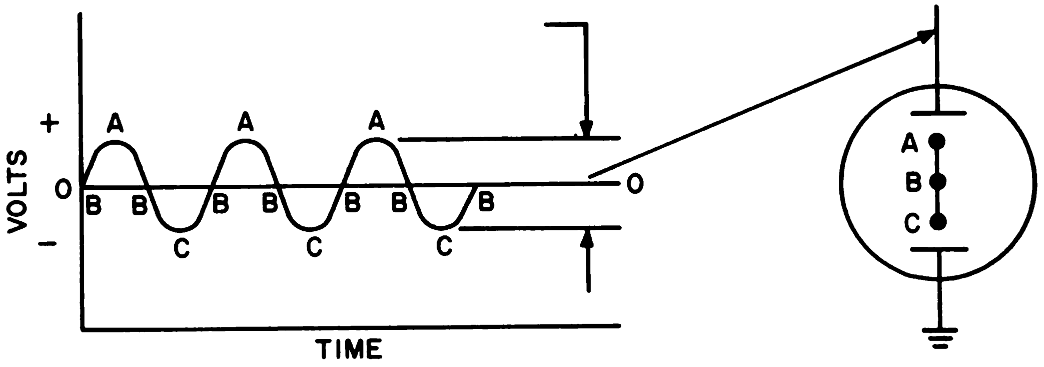
Obviously, with no vertical deflection present, the retracing electron beam would pass back over the same path it used from A to C. To insure that no vertical signal may deflect the return trace from its course, a pulse may be used to shut off the CRT during retrace time. This pulse is called the BLANKING pulse.

The blanking pulse is a nonsymmetrical (square wave) waveform that has the same frequency as the sawtooth. Its positive portion has the same time duration as trace time, while the time duration of the negative portion equals retrace time. As is shown in the illustration below, the blanking pulse is usually applied to the CRT control grid, in step with the sawtooth which is being applied to the horizontal deflection plates. As the electron beam moves from left to right, the positive portion of the blanking pulse brightens the trace. The negative portion of the blanking pulse biases the CRT into cutoff as the beam is snapped back during retrace.

VERTICAL — The action of the vertical deflection plates is identical to the horizontal as concerns electron beam motion. That is, the polarity of the vertical voltage waveform determines direction of deflection, while



37. BLANKING THE RETRACE



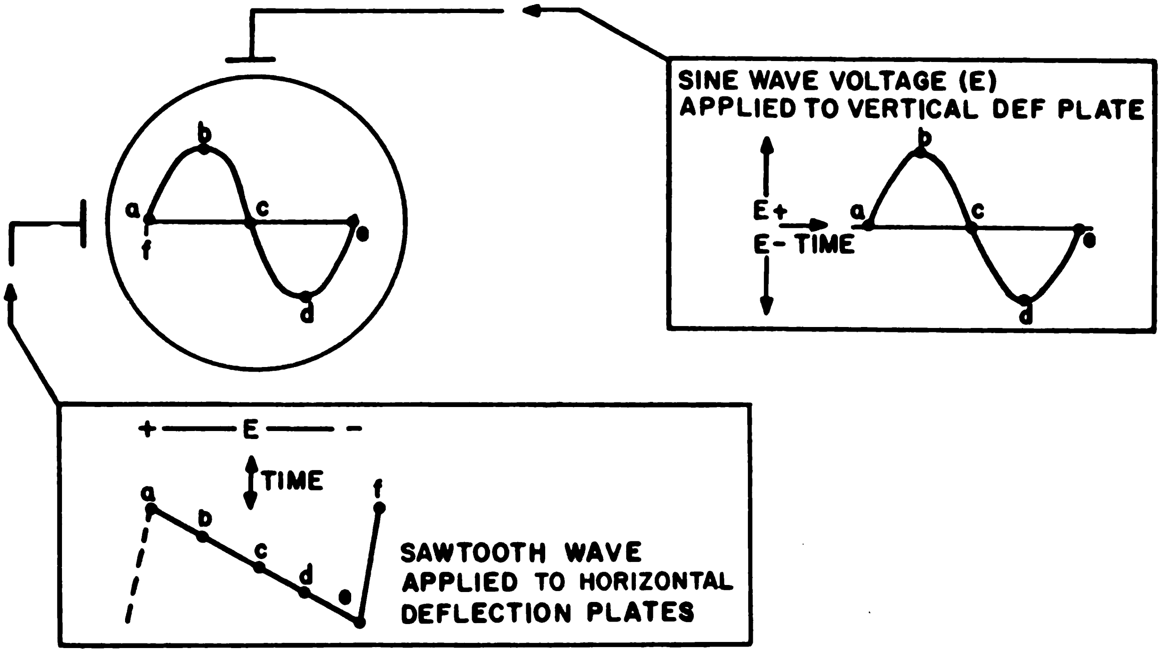
38. VERTICAL DEFLECTION

magnitude determines amount. Shown above is an example of vertical deflection. Note that even though the applied signal is a sine wave it generates a straight line in the absence of any horizontal deflection voltage.

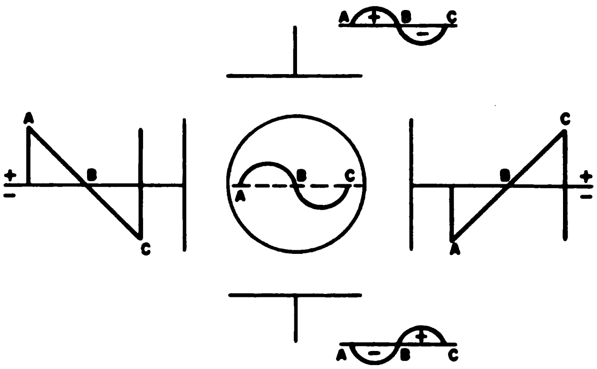
COMBINED DEFLECTION

If a sawtooth voltage is applied to the horizontal deflection plates at the same time that an AC voltage is applied to the vertical deflection plates, there will be a deflection of the electron beam which is a result of the combined effect of both voltages. As shown above, at the first instant the sawtooth is maximum positive and the electron beam is attracted toward the left plate. At the same time, the AC applied to the vertical plates is at zero volts, so the electron beam will pass exactly between the vertical plates (Point A). The result is such that the beam will strike the screen at the extreme left.

At b the sawtooth becomes less positive and the beam is attracted less strongly to the left while the vertical signal is increasing in a positive direction causing the beam to move upward. The beam will follow the combined efforts of both signals, striking the screen in a gradual curve, upward and to the right.



39. COMBINED VERTICAL AND HORIZONTAL DEFLECTION



40. BALANCED PUSH-PULL OPERATION

This continues until one-fourth way through the sequence, at which time the AC will be maximum positive (b) and the beam will be at its maximum upward excursion. The AC then begins to decrease from maximum positive toward zero, causing the beam to be attracted less strongly toward the upper plate, and the sawtooth wave continues to be less positive attracting the beam less and less to the left. Now the beam strikes the screen in a gradual curve downward and right toward the screen's center.

At c, both signals are at zero and the beam passes exactly down the center axis of the CRT and strikes the screen in the center. As both voltages continue to change, they begin going negative and repell the beam away from them. The combined effect will be that the beam strikes the screen in a gradual curve, downward and to the right until three quarters through the sequence (d). Now the AC is maximum negative and the beam is at its maximum downward excursion. The AC then begins to decrease from maximum negative toward zero volts, causing the beam to be less repelled by the upper plate. Meanwhile, the sawtooth wave continues to become more negative, repelling the beam more and more toward the right so that the beam strikes the screen in a gradual curve, upward and to the right until the completion of one full sequence (e). At this time the sawtooth is maximum negative and the AC is again back to zero volts. This places the beam at the right hand side of the screen which is the end of one sweep. As you have no doubt noticed, the beam traced a pattern on the screen which was a reproduction of the signal applied to the vertical plates. This feature is what makes the oscilloscope such a useful tool for troubleshooting in electronic equipment. We will study more about these features in the next few topics.

In normal practice, signal and sweep voltages are applied in balanced push-pull to the vertical and horizontal deflection plates, as shown below. There are many reasons for this such as making the scope more sensitive to smaller signals, and reducing distortion problems.

In this topic you learned about a special kind of vacuum tube called a cathode ray tube. The invention and improvement of this tube has enabled the visual display of many electronic phenomena which were formerly only available as meter indications or audio signals.

Some of the more important applications of cathode ray tubes are in oscilloscopes, television and as radar and sonar indicators. In the next topic you will study one of these applications; the general purpose oscilloscope.

TOPIC 2: GENERAL PURPOSE OSCILLOSCOPE OS-8E/U

You Are Now Going to Learn:

1. The basic oscilloscope design.
2. The principles of oscilloscope operation.
3. The uses of the oscilloscope.

You Will Acquire Skill in:

1. Operation of a general purpose oscilloscope.
2. Measuring voltages with an oscilloscope.
3. Checking phase relationships with the oscilloscope.
4. Measuring frequency with an oscilloscope.

Discussion Points for this Topic Are:

1. The oscilloscope.
2. Operation.
3. Controls.
4. The oscilloscope graticule.
5. Oscilloscope probes.
6. Oscilloscope uses.
7. Experiments.
8. Review and summary.

INFORMATION AND DISCUSSION:

THE OSCILLOSCOPE

Modern electronic equipments contain hundreds, even thousands of vacuum tubes. To check each tube every time there is an equipment failure is not practical, so there are built in "test points" located throughout the equipment. An oscilloscope, properly applied to these test points, will enable the competent technician to isolate or localize a casualty. Once the trouble has been isolated to a particular unit or stage, the technician can use appropriate test equipment to find the malfunctioning component.

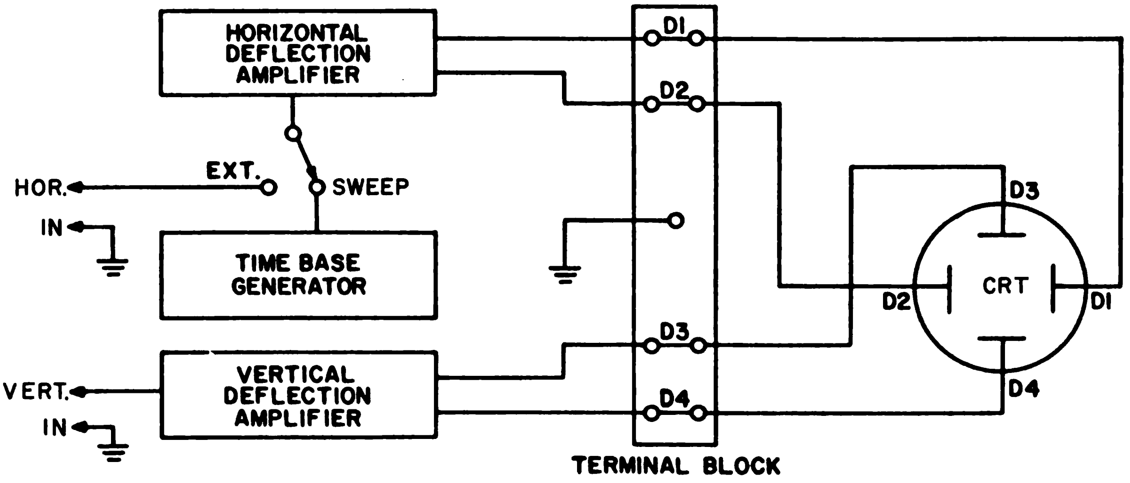
The oscilloscope is a test instrument consisting of a cathode ray tube and associated circuits. Due to the persistency of the CRT's phosphor coating, the screen will glow for a brief time after it has been struck by the electron beam. Thus, it is a good device for viewing waveforms.

Recalling that a voltage waveform is simply a plot of instantaneous voltage amplitudes against TIME, you can appreciate the work expended in laying out with a straight edge and pencil, a cycle of a signal voltage. The oscilloscope can do this for you if the circuits associated with the CRT are of proper design. That is, if the CRT has a sawtooth voltage waveform applied to its horizontal plates, then TIME can be laid out left-to-right just like a graph.

If the voltage that you wish to view is connected to the vertical plates, then the instantaneous values are being plotted up and down. Topic 1 used just such an example to demonstrate combined deflection.

The illustration on the facing page is a simplified block diagram of a general purpose oscilloscope. No matter how elaborate or sophisticated later oscilloscopes you study become, they are still comprised of the same basic units.

In the block diagram, the time base generator provides the sawtooth of voltage, the frequency of which is adjustable. When used as time, the sawtooth is coupled to the horizontal deflection amplifier. Switching allows



41. OSCILLOSCOPE, SIMPLIFIED BLOCK DIAGRAM

inputs other than time to be coupled to the horizontal deflection plates. With time generated horizontally, the signal to be seen is connected to the vertical plates through the vertical deflection amplifier. Not shown is the oscilloscope power supply that provides all necessary AC and DC power to operate the various circuits.

OPERATION

The Oscilloscope OS-8E/U, is the general purpose oscilloscope that is to be discussed in this topic and the scope that you will use for the practical work. It is used throughout the Navy for maintenance. Becoming adept in its use will assure you of success in the use of the more modern scopes you are study in this course and be expected to use in the fleet.

So that you may better understand this and other scopes' operation, the functional signal flow of its internal circuits will be covered. For the remainder of this topic, refer to the foldout diagram at the end of this topic entitled "Oscilloscope, Signal Flow Block Diagram". Notice that the circuits are divided functionally into sections; horizontal, vertical, sweep, and synchronizing.

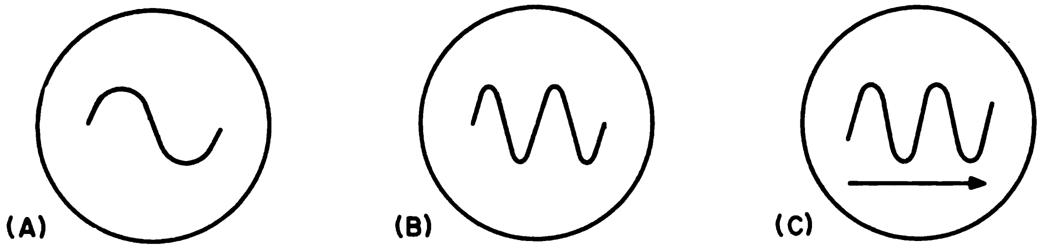
In the vertical section, the normal input is some type of AC signal. This signal is applied to the VERT. ATTEN. switch so the larger signals may be reduced in size when necessary to keep from overloading the input circuits.

On the VERT. ATTEN. switch there are three AC positions and one DC position. The DC position is effectively a short circuit past the switch so that when a DC voltage is applied at the vertical DC input jack it is bypassed directly to the first DC amplifier stage.

The AC signal, after the attenuator, is applied to the vertical cathode follower. The variable VERT. GAIN control is in the cathode circuit of this stage. From this stage the signal is sent to amplifiers where the signal is amplified and inverted to provide two signals, 180 degrees out of phase, to be applied to the vertical plates of the CRT. A portion of the signal is also taken from the cathode of the vertical output tubes to be applied as internal sync to the SYNC SELECTOR switch.

The horizontal section has a five position switch to select the input to the horizontal amplifiers. The normal position is the SWEEP position in which a sawtooth signal is applied from the TIME BASE GENERATOR as shown on the block diagram.

If an AC signal is to be applied to the horizontal section it may be applied through the HOR. ATTEN. switch in three different AC positions.



42. SWEEP/SIGNAL FREQUENCY RELATIONSHIPS

In the DC position the signal is applied directly to the first DC amplifier. Assuming that the HOR. ATTEN. switch is in the SWEEP position, a sawtooth is applied to the horizontal cathode follower. The HOR. GAIN control is in the cathode circuit of this tube. The signal is then sent to the first DC amplifier which amplifies and inverts the sawtooth and sends two sawtooth waveforms, 180 degrees out of phase, to the output amplifier.

The HOR. POS. control is also in the first DC amplifier circuit. The signal is further amplified in the output DC amplifiers and sent to the two CRT horizontal plates 180 degrees out of phase.

From the sweep section comes the sawtooth that represents TIME across the face of the CRT. The sawtooth is sent to the horizontal amplifier via the HOR. ATTEN. switch in the SWEEP position. Amplified and split in phase, the sawtooth is felt at the horizontal plates. In the flow diagram, the input into the time base generator is the output of the sweep oscillator, a square wave. This oscillator also feeds the intensity modulation amplifier, the output being the blanking pulse. Thus, proper frequency and time relationships are established for these two signals.

The fourth section of the scope is the synchronizing section. Its purpose is to establish a suitable timing relationship between the sweep and the signal to be viewed. Sweep frequency is selected at the sweep section, but is stabilized to some multiple of the signal frequency by this synchronizing section. Three ways are available:

(1) the SYNC SELECTOR switch may connect a portion of the signal being viewed (INTERNAL).

(2) the signal itself (EXTERNAL).

(3) the 60 cycle power frequency (LINE).

In effect, the synchronizing section provides triggering for an otherwise free running multivibrator.

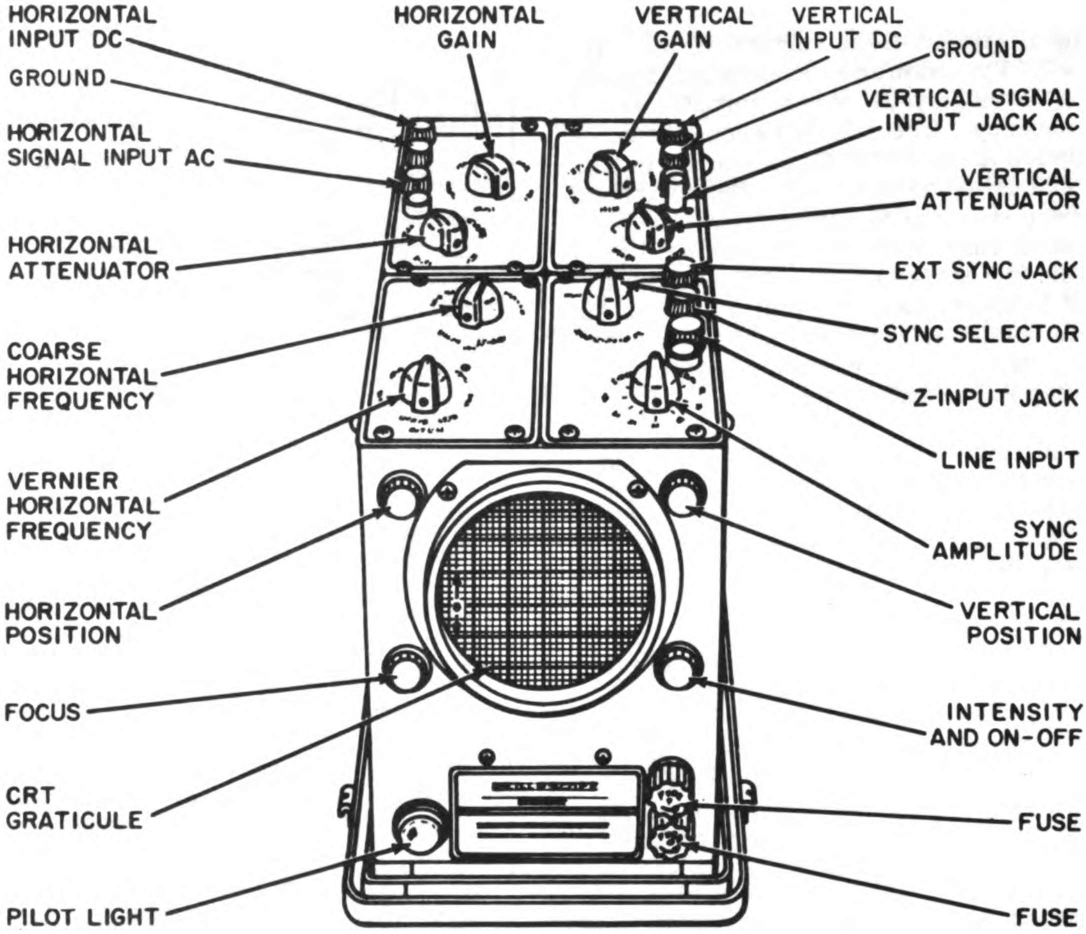
The illustration above shows some sweep frequency/signal frequency relationships. In (A), the signal frequency equals sweep frequency, while at (B), the signal frequency equals two times sweep frequency. At (C), there is no multiple relationship and the signal appears to flow across the CRT, left to right.

Another input is also possible to the intensity modulation amplifier. This is the Z AXIS input applied to the Z AXIS input jack. A negative trigger applied at this jack will cause bright spots to appear on the sweep at the frequency of the Z AXIS input signal. If the input frequency is known and stable, the oscilloscope sweep can then be calibrated in time from one bright spot to the next. A positive trigger applied at the Z AXIS jack will cause blanking or dark spots on the sweep.

CONTROLS

The controls explained here and shown on the facing page are the controls found on most oscilloscopes. Locations and names of the controls will vary on different scopes, but functions of the controls will vary little.

A. INTENSITY control — this control usually serves two purposes. It is the POWER ON-OFF switch and the brilliance control. It should be adjusted for convenient viewing. When the scope is not in use, the intensity should be turned down so that the beam cannot be seen, otherwise a spot will be burned in the phosphor coating on



43. CONTROLS, OSCILLOSCOPE OS-8E/U

the internal face of the CRT. On some scopes the POWER ON-OFF switch is a separate control.

B. FOCUS control — this control adjusts the clarity of the picture. It should be adjusted for the most clearly defined scope pattern.

C. VERT. POS. control — is employed to vary the vertical position of the CRT pattern. Counterclockwise rotation of the knob moves the pattern down, while clockwise rotation moves it up.

D. HORIZ. POS. control — is employed to vary the horizontal position of the pattern. Counterclockwise rotation moves the entire pattern to the left. Clockwise rotation shifts the pattern to the right.

E. VERT. GAIN control — is used to control the vertical size of the pattern.

F. HORIZ. GAIN control — is used to control the horizontal amplitude or width of the pattern.

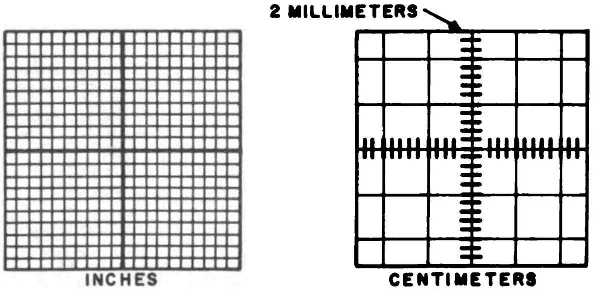
G. VERT. ATTEN. switch — usually has two positions, DIRECT or AMPLIFIER. It is normally left in the AMPL. position. In the DIRECT position, the waveform to be viewed is applied directly to the vertical plates of the CRT without any amplification. At this time the VERT. GAIN control has no effect on gain. In the AMPL. position, the signal is first fed into the vertical amplifiers to enlarge the waveform before it is applied to the vertical plates.

H. SYNC SELECTOR control — usually has three positions; INT, EXT, and LINE. On the INT position a portion of the signal applied to the vertical plates is fed to the horizontal sweep circuit synchronizing the sweep circuit to the frequency of the signal applied to the vertical plates. In the EXT position an external signal source may be employed to synchronize the sweep frequency. The external signal would be applied at the SYNC IN jack or terminal. When using external sync, the horizontal sweep starts at the same point in relation to time on each cycle making it possible to observe phase relationship. In the LINE position, a small portion of the line voltage is fed to the sweep circuits and used to synchronize the horizontal sweep to the line frequency.

I. SYNC AMPLITUDE (LOCKING) control — is used to adjust the amount of the sync fed to the sweep circuits. Proper adjustment of this control will stop the signal from running across the CRT.

J. HOR. ATTEN. switch — controls the input to the horizontal deflection amplifier. In the SWEEP position, the sawtooth from the time base generator is applied to the amplifier. This is the normal position for this switch. In its other positions, the switch reduces the amplitude of externally applied horizontal signals by the factor marked on the switch.

K. COARSE HOR. FREQ. control — is used to set the frequency of the time base generator in a series of steps. Each step covers a range of frequencies.



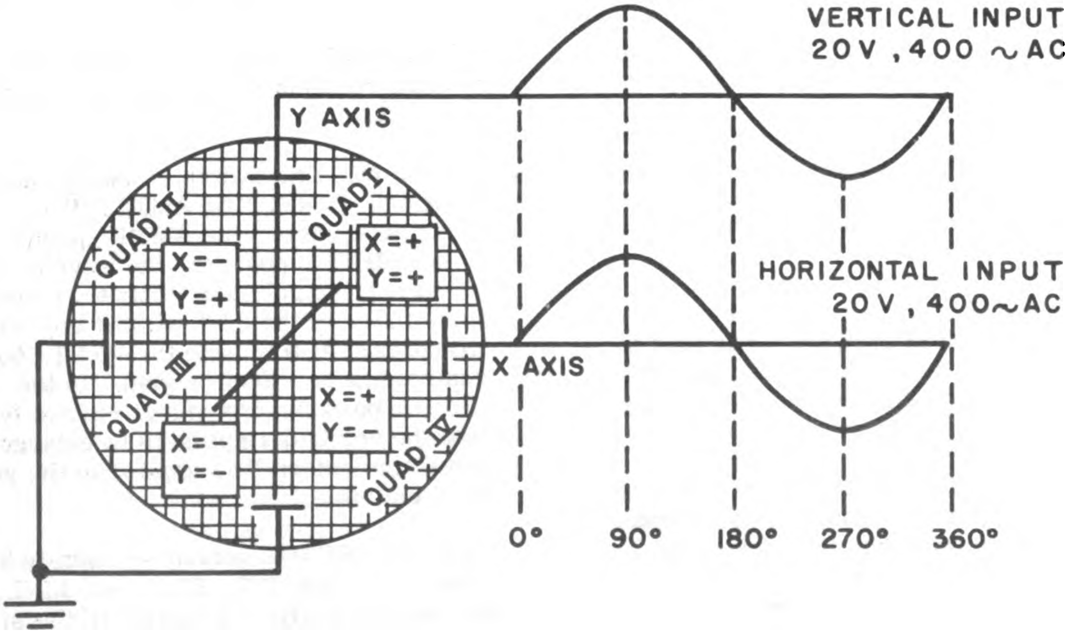
44. TYPES OF OSCILLOSCOPE GRATICULES

L. VERNIER HOR. FREQ. control — refines the setting of the COARSE control for a specific time base generator frequency output.

M. VERT. INPUT (AC & DC) JACKS — connect signals to the scope to be viewed.

N. HOR. INPUT (AC & DC) JACKS — connect signals to the scope for use as external time bases or to generate special patterns.

O. Z-INPUT JACK — connects external triggers for marking increments of TIME along the time base.



45. THE GRATICULE AS A SYSTEM OF RECTANGULAR COORDINATES

P. EXT. SYNC JACK — connects external triggers for sync control.

THE OSCILLOSCOPE GRATICULE

The use of an oscilloscope graticule makes analysis of observed waveforms less difficult. A graticule is composed of a transparent plate having ruled lines both horizontally and vertically. The projections of the ruled lines have divisions either in inches or centimeters as shown below. Inch divisions are usually subdivided into 1/10 inch lines and the centimeter divisions are usually subdivided into 2/10 centimeter marks (2mm).

The graticule is placed in front of the face of the CRT. It is held in place by a bracket and can be replaced by the technician with a graticule of another tint or projection.

The graticule can be visualized to represent the four quadrants of the system of rectangular coordinates. The vertical deflection along the Y axis and the horizontal plates cause deflection along the X axis. This is illustrated in the lower figure on the preceding page. It can also be seen that polarity of the input signals determines the quadrants to which the beam will deflect. Quadrant III, for example, will have the beam deflected to it if both the X and Y inputs are negative. Polarities for the other quadrants are similarly shown. Also note the two signals applied to the plates. They are equal in amplitude, frequency, and in phase. The tilted straight line shown is the type of presentation these signals will cause.

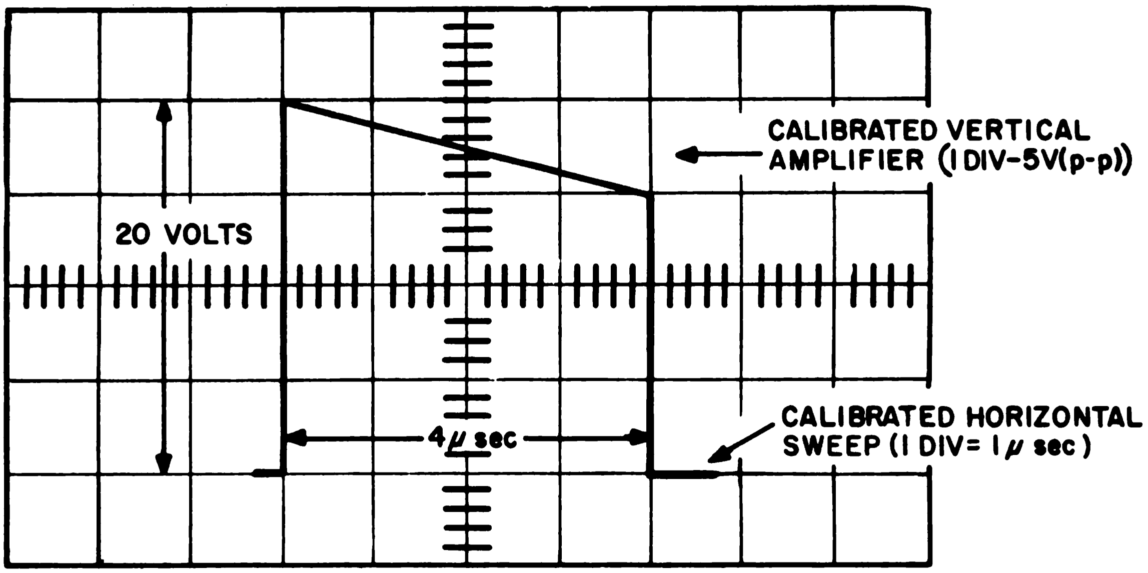
Oscilloscopes that use a calibrated horizontal sweep may have TIME/CM control. When one microsecond time is selected, each centimeter on the graticule is equal to one microsecond time on the horizontal sweep. Other scopes may have a TIME/DIV control. When one microsecond time is selected, each large square on the graticule is equal to one microsecond time on the horizontal sweep.

When a VOLTS/DIV control is set to the 5 position, each vertical division on the graticule is equal to five volts. The amplitude and time base of waveforms can be precisely measured as shown below.

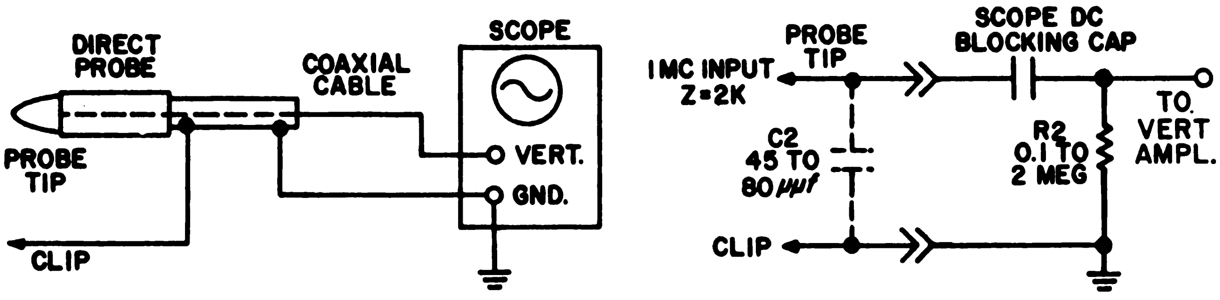
The graticule provides a standard reference for oscilloscopes when they are used for making phase comparison, amplitude and time measurements and observing Lissajous patterns of waveforms.

OSCILLOSCOPE PROBES

The LOW CAPACITANCE probe is the most commonly used probe with oscilloscopes and will be studied at this time.


20 VOLTS
4μ sec
CALIBRATED VERTICAL AMPLIFIER (I DIV-5V(p-p))
CALIBRATED HORIZONTAL SWEEP (I DIV= I μ sec)

46. AMPLITUDE AND TIME MEASUREMENT



(A) DIRECT PROBE FOR TYPICAL SCOPE

(B) SCOPE INPUT CIRCUIT

47. OSCILLOSCOPE LOADING

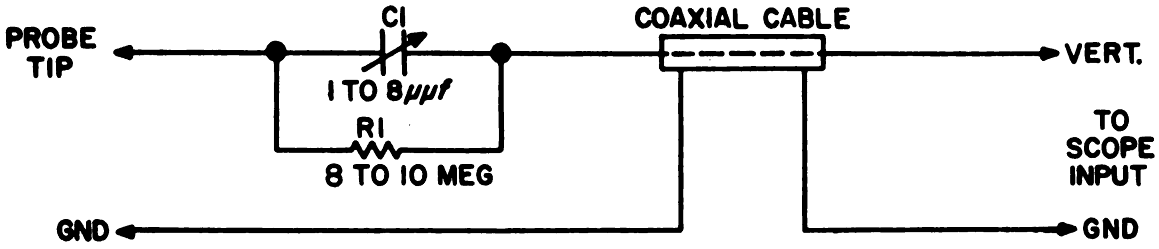
The internal vertical input circuit of an oscilloscope consists of resistance and capacitance. The amount will vary on different types of scopes. For instance, the typical input series resistances are on the order of 0.1 megohms, and typical shunt capacitances are on the order of 15 to 30 pf. Added to this capacitance is approximately 30 to 50 pf. (or more) distributed capacitance when using a direct probe and coaxial input cable. Addition of this shunting resistance and capacitance to some circuits under test would have virtually no noticeable effect on their operation and on the voltage and waveform present at the test point. However, in many cases, this amount of added capacitance may be sufficient to detune resonant circuits, or to capacitively load a circuit enough to seriously distort the waveforms under observation, or alter peak-to-peak voltage values.

This would particularly be apparent if the circuit had high impedance or relatively high frequency. For example, the input impedance presented to a circuit with a signal frequency of 1 MC. by a typical service scope would be approximately 2,000 ohms, as shown above. To prevent excessive circuit loading, it is necessary to decrease the normal input capacitance (increasing the input impedance). This may be accomplished in a simple and convenient manner by means of a compensated R-C type of circuit-isolation probe commonly known as a LOW CAPACITANCE or HIGH IMPEDANCE probe because of its function.

The simplest type of conventional frequency-compensated R-C divider LOW CAPACITANCE probe for use with scopes is shown in the upper illustration on the facing page. A small semivariable tubular or ceramic trimmer-type capacitor C1, shunted by a high resistance R1, is connected in series with the hot lead of the coaxial cable to the scope. This places the parallel combination in series with the overall 0.1 to 2 megohms input resistance and the 45 to 80 pf. input capacitance of the scope.

The equivalent circuit is shown in the bottom illustration on the facing page. It can be seen that an R-C divider circuit results. The DC blocking capacitor of the scope is shown, but since it has a large capacitance and therefore a very low reactance, it may be neglected in all high frequency AC test signal combinations. Since the resultant capacitance of two capacitors in series (C1 and distributed capacitance C2) is less than that of the smaller capacitor, the effective input capacitance at the probe may be made almost any desired fraction of the overall scope input capacitance C2 by suitable choice of the value of the series capacitor C1 in the probe. The use of the resistor R1 also reduces the effect of input capacitance of the scope.

Furthermore, since the two capacitors and the two resistors form a voltage divider for applied AC voltages, and the AC voltages which appear across the individual capacitors



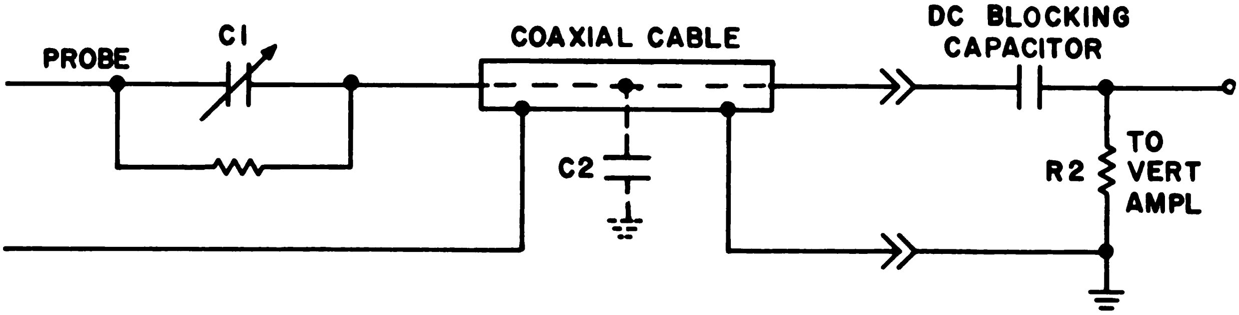
48. LOW CAPACITANCE PROBE

are in inverse ratio to the capacitances, and directly proportional to the resistances, it follows that the increase in the overall scope input impedance and the reduction of the overall scope input capacitance by a certain ratio is accompanied by a loss of AC signal voltage (in the same ratio) entering the scope. This loss is usually referred to as the attenuation of the probe.

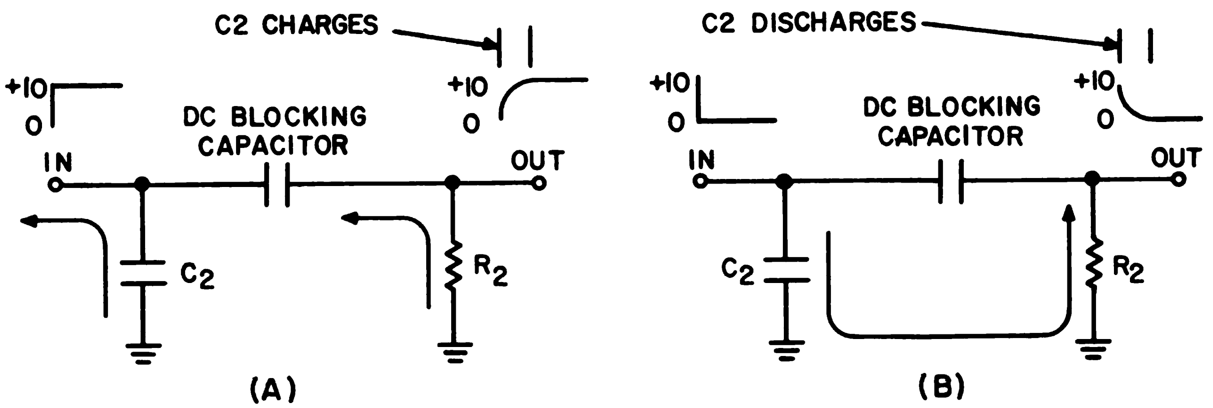
The series capacitor and resistor are usually chosen and adjusted to have a value which makes the attenuation ratio a convenient figure; usually 10:1, or 100:1. The 10:1 probe is the most widely used in service work.

Since the AC voltage stepdown ratio is then a decimal fraction, use of the probe with a calibrated scope does not destroy the voltage calibrating factor (or deflection sensitivity calibration) of the scope. The decimal point is merely moved in the initial calibrating factor of the scope. Thus, if the vertical deflection sensitivity of a particular scope is set for 0.02 volts/inch when it is used with its direct probe and cable, it becomes 0.2 volts/inch when it is used with a 10:1 low capacitance probe.

The shunt capacitance C2, in addition to overloading a circuit under test, affects the waveform shape. Assume that an input of 1 MC is a square wave. Its period is 1 μsec. The DC blocking capacitor is large so that it is effectively a short circuit to this signal. The scope input should be a square wave also. Since the DC blocking can be considered a short circuit at this frequency, C2 is actually in parallel with R2. Now C2 is small and can charge and discharge quickly with respect to the time for one cycle of the 1 MC signal



49. PROBE/SCOPE EQUIVALENT CIRCUIT



50. SIGNAL DISTORTION

to occur. But, when C2 is charging (A above) little or no current is drawn through R2. Thus, the voltage waveform across R2 does not follow the input. When the input falls to zero, the current through R2 does not drop instantly, but is detained by C2 discharge current as shown in B above.

Reduction of C2 to zero should eliminate any distortion, although even with careful design, some capacitance exists. C1 in the probe is in series with C2 and is adjustable. Recall that capacitors in series act like resistors in parallel. Thus the total capacitance will be less than C1 alone.

Compensation of this very important probe can not be overemphasized. If you expect to get accurate representations on your scope of the waveforms in the equipment you must frequently check the compensation of this probe.

In the illustration on the facing page the low capacitance probe has been connected to the scope input circuit. The top diagram at (A) shows input and output signals with the probe incorrectly compensated.

The bottom diagram at (B) shows the same input with the correct output because C1 has been correctly adjusted. Note that the output waveform amplitude has been attenuated in both cases.

OSCILLOSCOPE USES

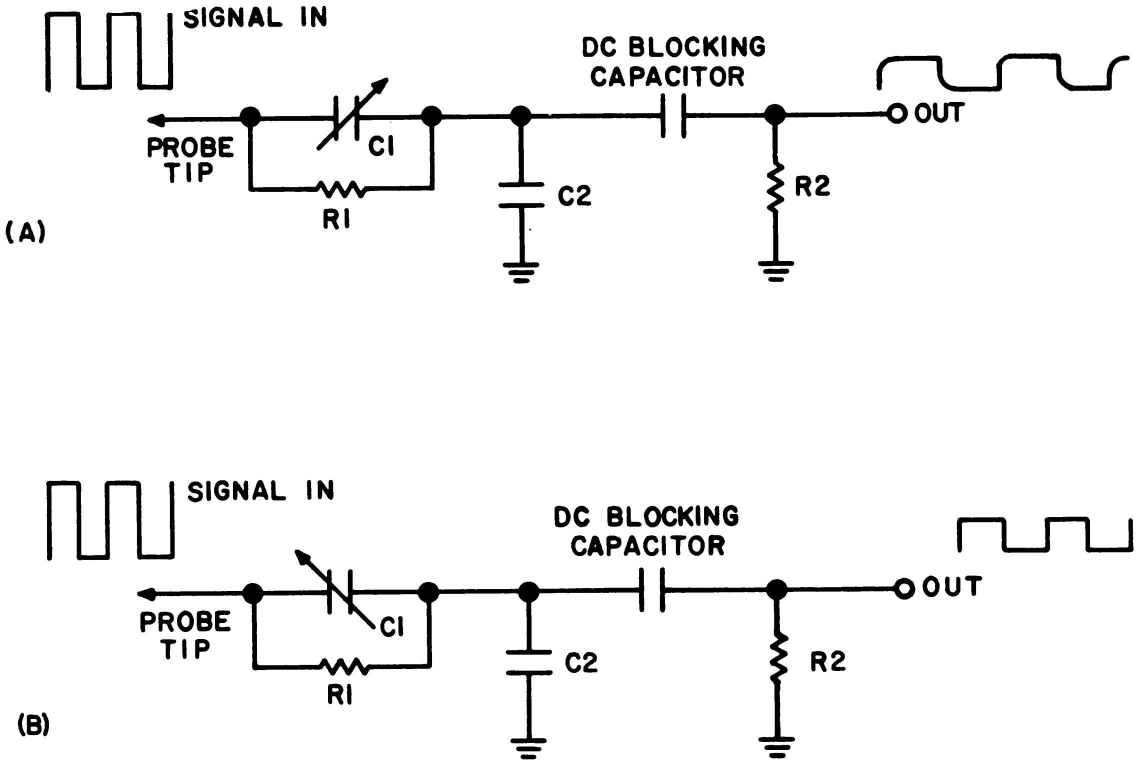
In addition to its use in observing waveshapes, the oscilloscope is used for measuring voltages, frequency, phase relations, and time (period) of a waveform.

A voltage is measured by comparing the deflection it produces with the deflection produced by a known voltage. Vertical gain controls are not changed during the comparisons. Since deflection is proportional to voltage, this is a very good method for measuring peak and peak-to-peak voltage values.

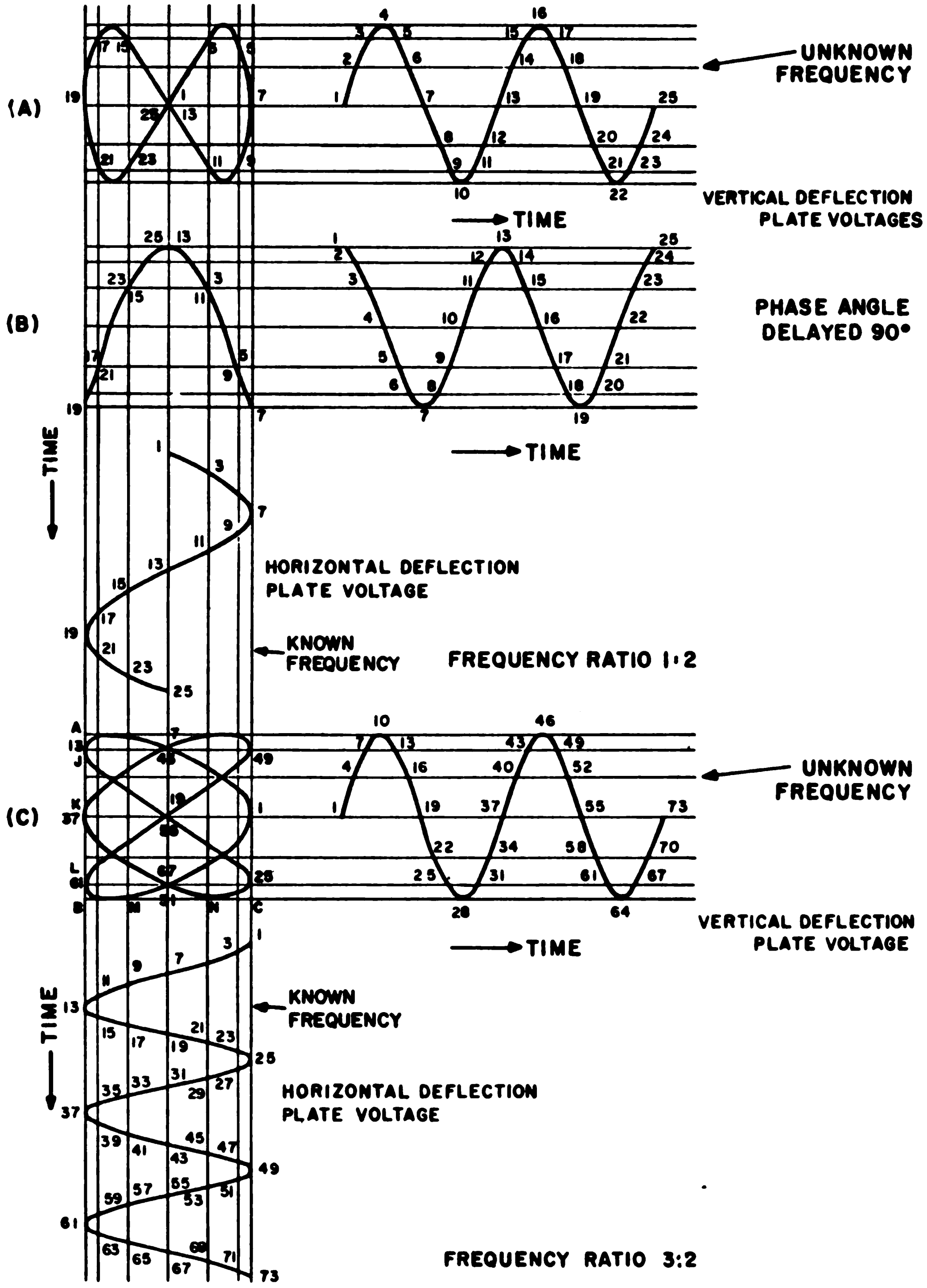
First apply the known voltage and adjust the vertical controls for a desired pattern size. Using the graticule, measure the peak or peak-to-peak value. Next, apply the unknown voltage and take a similar measurement. By comparing the deflections obtained, a ratio is obtained and the unknown voltage determined. The RMS value is then .354 times the peak-to-peak value.

Frequency determination can be accomplished by two methods. The first is to compare the unknown frequency with a known frequency by applying them one at a time to the vertical deflection system and obtaining the ratio of number of cycles appearing. It is necessary that the horizontal sweep (TIME) controls not be changed. Unless the two frequencies are an integral ratio of one another, this method provides only a good approximation.

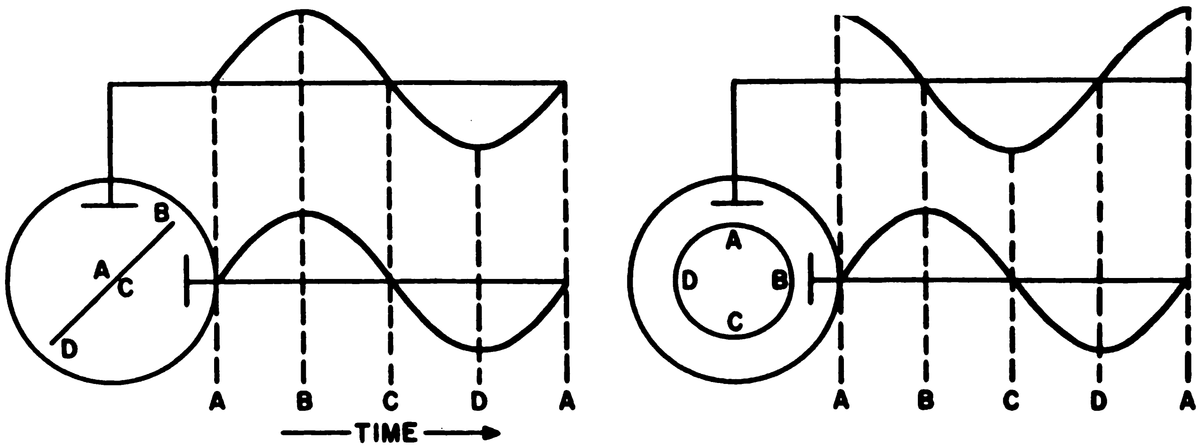
The second method for determining the frequency of a sine wave, is to apply the unknown frequency to the vertical plates while a known frequency is applied to the horizontal plates. Some frequency patterns resulting from the application of known frequencies are



51. PROBE COMPENSATION RESULTS

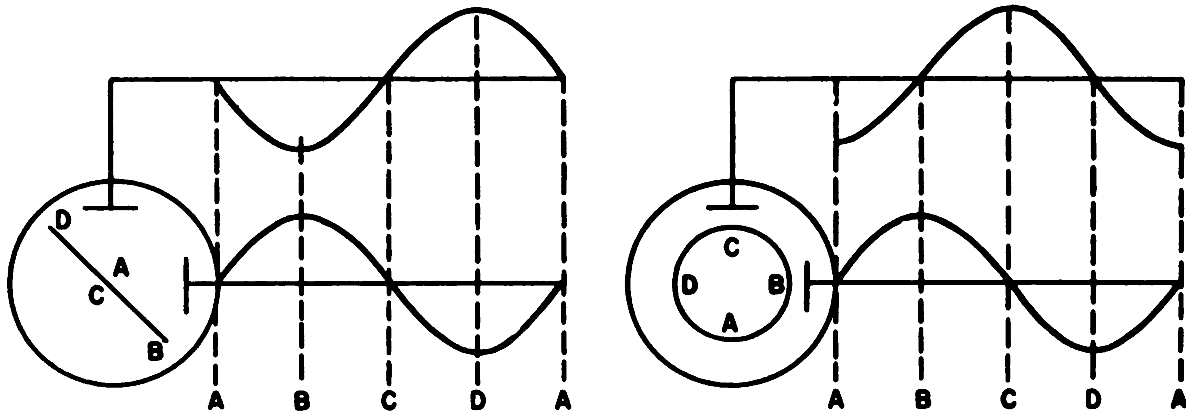


52. LISSAJOUS PATTERNS



A. IN-PHASE INPUTS

B. 90° PHASE INPUTS



C. 180° PHASE INPUTS

D. 270° PHASE INPUTS

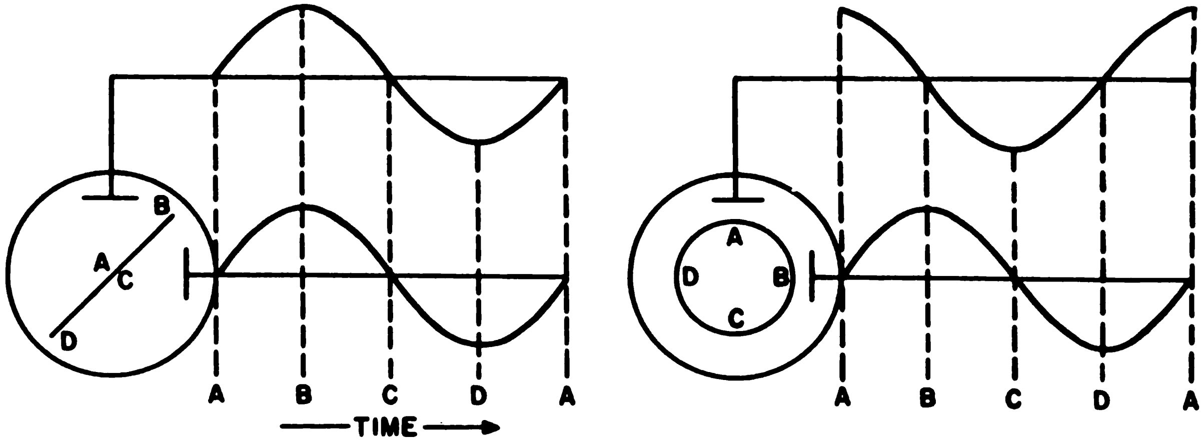
53. PHASE COMPARISON

shown on preceding page. Once the pattern is obtained, the peaks are counted along its top or bottom edge and at either side. Thus in (A) or (B), the ratio of the unknown to the known is 2:1. In (C), the ratio is 2:3. Note that in (A) and (B) the ratio is the same but the patterns are dissimilar. This is because the phase angle of the unknown has been shifted 90 degrees in the (B) example. However, the ratio is still 2:1 and you get the ratio is still 2:1 and you get the same peak count.

The application of sine waves to the vertical and horizontal plates of an oscilloscope in this fashion results in figures being generated on the screen which are called Lissajous patterns. The ratio of peaks is always determined by the signal frequencies regardless of phase relationships.

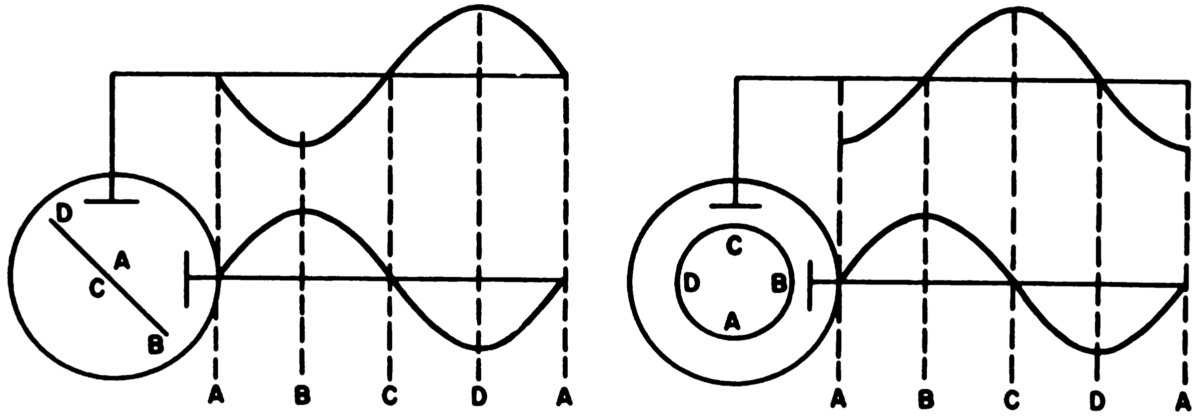
Lissajous patterns can also be employed to determine the phase relationship two sine waves. A simple pattern of this type is the circle. To determine phase relationship in this manner, the two signals must be of the same frequency and the same amplitude. Same amplitude in this case means at the deflection plates; the vertical and horizontal attenuation or gain controls providing the necessary adjustments to obtain this condition.

Shown above at (A), are two in phase sine waves of equal amplitude applied to the vertical and horizontal deflection plates. At time A, both signals are at zero amplitude, so the beam will not be deflected and will strike the center of the CRT screen. As both voltages increase in a positive direction (time A to B), the beam will sweep up and to the right at a 45 degree angle. From time B to C,



A. IN-PHASE INPUTS

B. 90° PHASE INPUTS



C. 180° PHASE INPUTS

D. 270° PHASE INPUTS

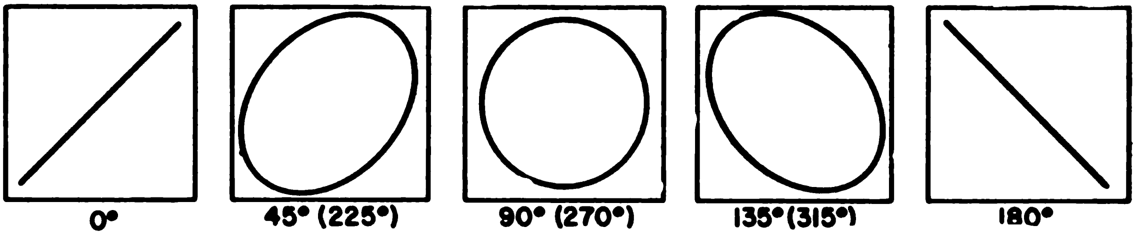
54. PHASE COMPARISON

both signals decrease to zero, and the beam will retrace to the center of the screen. On the negative half cycle, the beam will be deflected down and to the left to time D, then retrace to the center as the cycle ends. Electron beam deflection can be followed in the diagrams above for various out-of-phase inputs.

By analyzing (B) above in the same manner, it can be seen that two voltages applied 90 degrees out-of-phase, but of equal frequency and amplitude, will result in a circle. (C) shows the two voltages 180 degrees out-of-phase resulting in a straight line slanting to the left. Shown at top of facing page are a group of Lissajous patterns illustrating phase differences from 0 degrees to 360 degrees.

A second method of determing phase relationships will now be discussed. Recall that the horizontal sweep of the oscilloscope is TIME. Measuring phase relationship is to inspect the polarity and amplitude of two signals at the very same instant of time. If the start of TIME is controlled by one of the signals or a third signal related to them, then each signal will appear on the trace at some definite point.

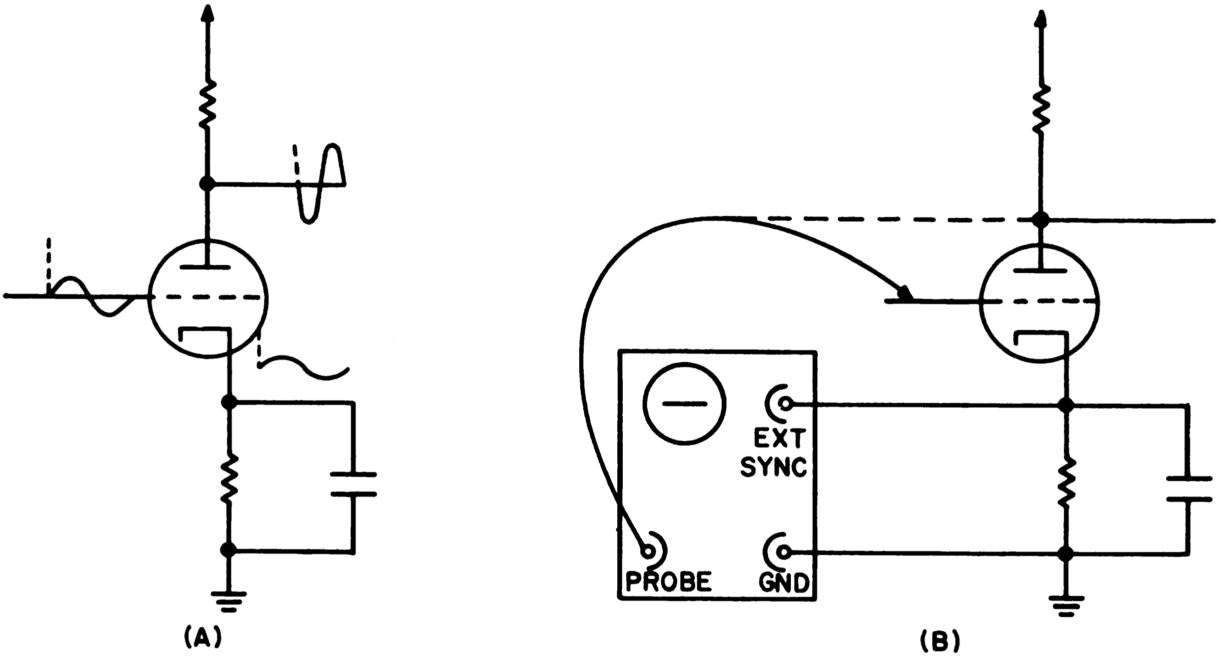
An example of this is the amplifier tube shown at bottom of facing page. The grid and the plate waveforms are 180 degrees out-of-phase with each other. They both however, have a definite relationship to the cathode phase. If the start of TIME is controlled (synched) by the cathode waveform, the above conditions will be met. First the grid voltage is applied to the vertical plates and the polarity at the start of the trace noted.



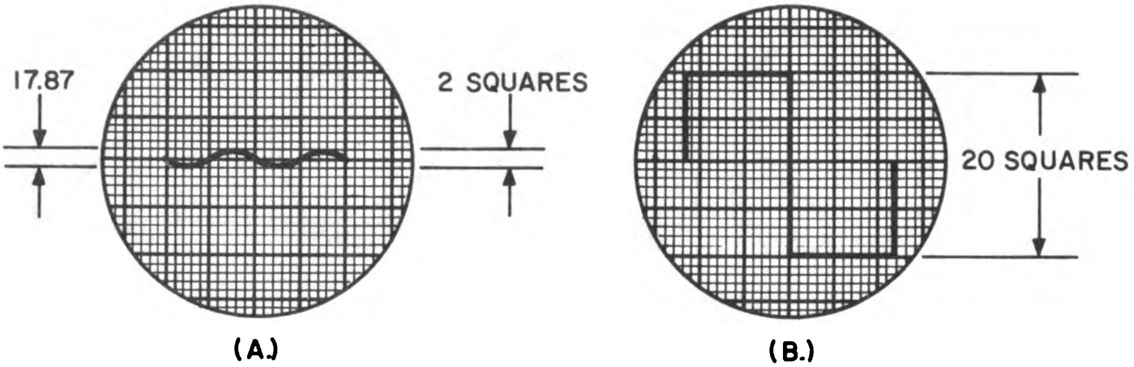
55. PHASE DIFFERENCE PATTERNS

Then the plate waveform polarity at the start of the trace is noted.

In the below illustration at (A), the waveforms are as you know they should be. Part (B) shows the connection of the scope. The waveshapes that appear on the CRT are shown at the appropriate elements and verify that the circuit phase relationships are correct. The scope sweep frequency is equal to that of the signal and the trace starts across each time the cathode voltage rises in a positive going direction from its zero axis.



56. PHASE RELATIONSHIPS IN AN AMPLIFIER



57. THE OSCILLOSCOPE AS A VOLTMETER

Experiments 3-2-1, Voltage Measurement, Use of the Graticule

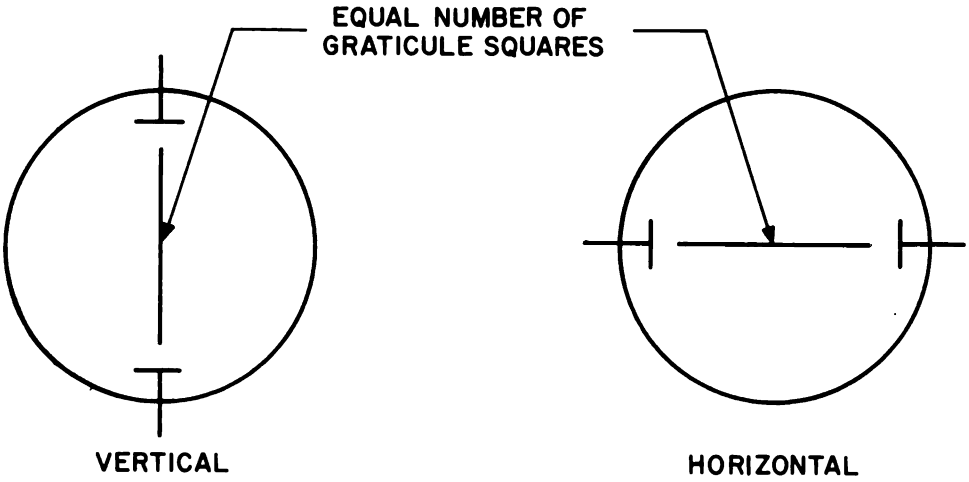
In this experiment you will determine the amplitude of the square wave on the plate, pin 5 (A-11L) of V3B in the Special Circuits chassis. First, you will calibrate the OS-8E/U to some known voltage. In the chassis, locate the power supply transformer T1 and its terminals 6 and 8. Across these terminals there should be 6.3 VAC filament supply. For the exact RMS value, check with the VTVM.

Convert the RMS value to P-P by multiplying by 2.828. 6.3 X 2.828 = 17.8 V P-P. This can also be read directly with a P-P voltmeter.

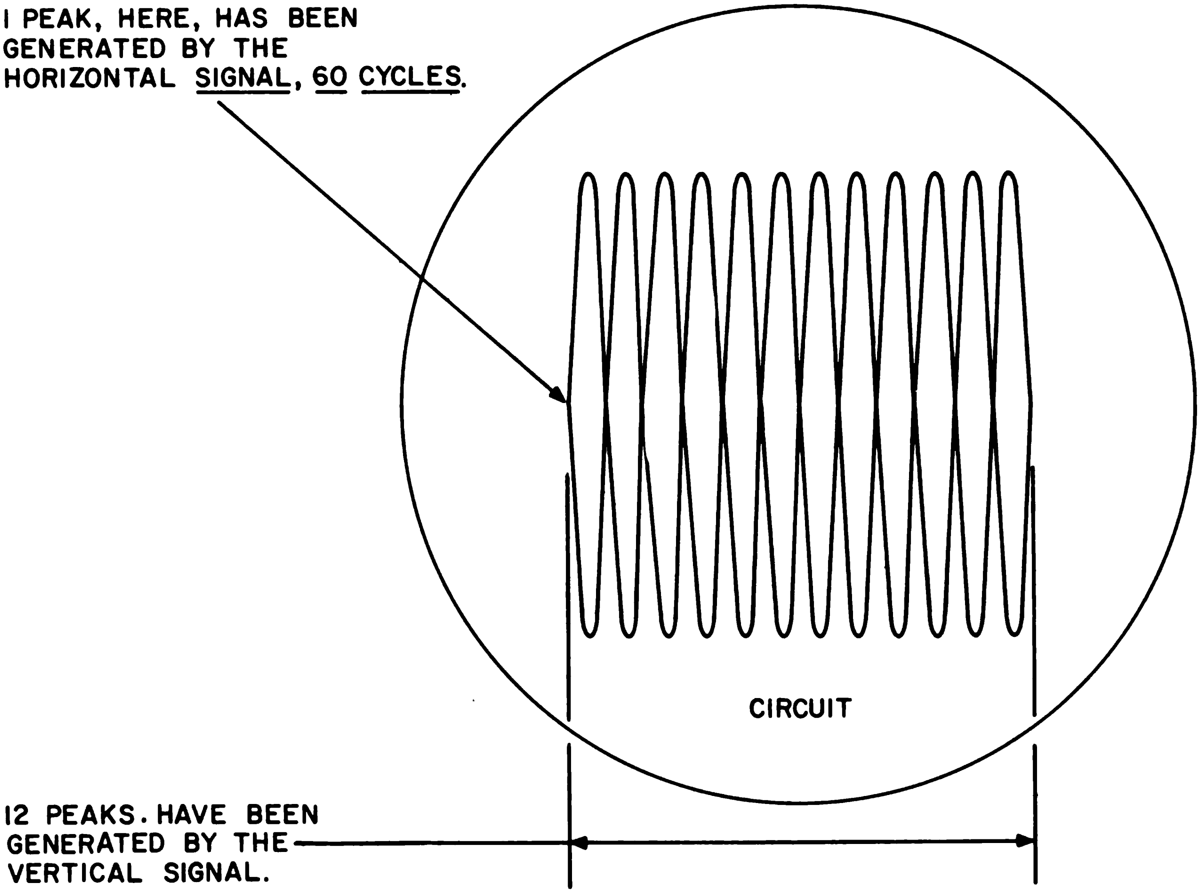
Connect the VERT. INPUT jack (AC) to terminal 6 of the transformer and the GND jack to terminal 8. Adjust the VERT. GAIN and/or the VERT. ATTEN. control on the scope until the signal is 2 squares (.2") P-P on the graticule as shown above at (A). The scope is now calibrated for voltage measurement and the vertical controls should not be disturbed for the remainder of the experiment. Each square equals 8.9 V P-P.

Next, connect the VERT. INPUT jack (AC) to the plate pin 5 (A-11L) of V3B. Adjust R-11 at the chassis for a square wave signal. Count the number of squares on the scope graticule that the signal covers vertically. This is the peak-to-peak value of the square wave. If the waveform covers 20 squares as shown above at (B), then its amplitude is 20 times 8.9 = 178 V P-P.

Many oscilloscopes have a P-P calibrating voltage available at a front panel jack for these types of voltage measurements.



58. LISSAJOUS PATTERN PRE-ADJUSTMENT


I PEAK, HERE, HAS BEEN GENERATED BY THE HORIZONTAL SIGNAL, 60 CYCLES.
CIRCUIT
12 PEAKS. HAVE BEEN GENERATED BY THE VERTICAL SIGNAL.

$$\frac{\text{PEAKS (UNKNOWN)}}{\text{PEAKS (KNOWN)}} = \frac{12}{1} = 12$$

UNKNOWN FREQUENCY = 60 X 12 = 720 CYCLES

59. FREQUENCY DETERMINATION

Experiments 3-2-2, Measuring Frequency, Lissajous Pattern Method

In this experiment you are going to determine the operating frequency of the Wien bridge oscillator is the special circuits chassis. You will accomplish this through the use of Lissajous patterns as covered earlier in this topic.

For the known frequency you will use the 115 VAC 60 cycle power input to the chassis. The 60 cycle signal will be applied to the horizontal plates while the output of the Wien bridge is applied to the vertical plates.

Before the Lissajous pattern can be properly observed, each input at the deflection plates must produce equal deflection of the beam. Apply one signal, then the other, adjusting the attenuators and gain controls for the same number of graticule squares of deflection as is shown above.

Once you have both inputs producing equal size deflections of the CRT beam, you are ready to generate the pattern. Connect both inputs into the scope, being careful not to upset the previously adjusted controls. The illustration above is the pattern that you should obtain. A small change in the frequency of the Wien bridge oscillator may be necessary for a stable presentation.

Experiments 3-2-3, Measuring Phase Relationships, Lissajous Method

In this experiment you will check the phase relationship of the signals at the tube elements of the Wien bridge oscillator. You should find that the grid and cathode signals are in-phase, producing a straight line. This Lissajous pattern will slant from the upper right quadrant down to the lower left quadrant.

The second relationship that you will check will be the plate-to-cathode. Here the Lissajous pattern will be a straight line slanting from the upper left quadrant down to the lower left quadrant. This indicates the 180 degrees out-of-phase relationship of plate-to-cathode.

Experiments 3-2-4, Measuring Phase Relationships, Externally Synchronized Sweep Method

This method was discussed detail earlier in this topic. The SYNC voltage will be taken from the cathode, pin 6, V2B (A-6L) in the Special Circuits chassis. Connect a lead from this point to the EXT. SYNC jack and select EXT. at the SYNC SELECTOR switch.

The phase of all other signals may now be observed. Stabilization of each waveform may be acquired by small adjustments of the SYNC AMPLITUDE (LOCKING) control along with the VERNIER HOR. FREQUENCY control.

Check as many wave forms as you can in the time alloted.

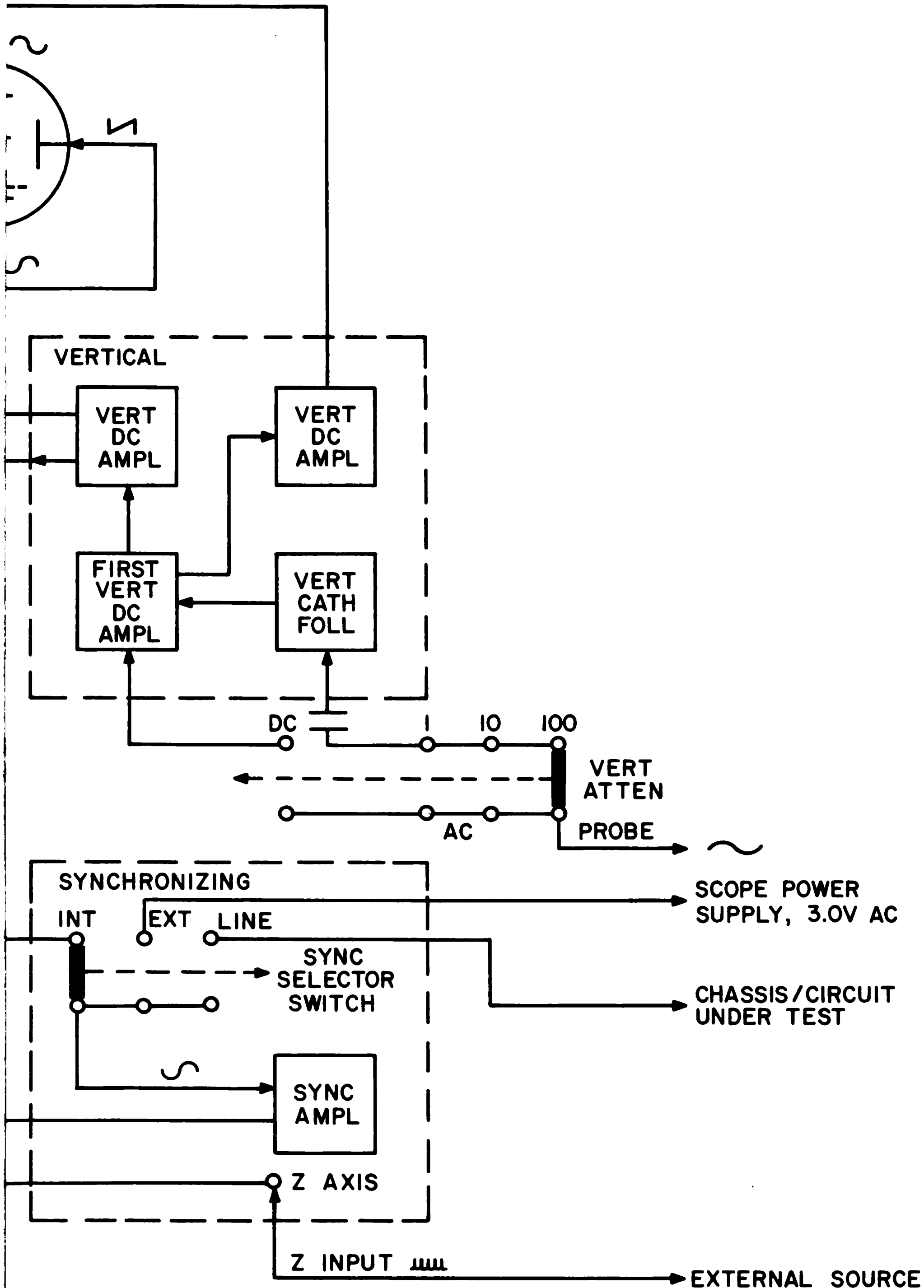
The first step in this experiment is to adjust both the horizontal and vertical inputs to the same deflection amplitude. The horizontal input will be from the cathode, pin 6, V2B (A-6L), in the Special Circuits chassis. The vertical input will be the grid signal, pin 4, V2B (A-5L). These adjustments are done separately. Once the adjustments are made, connect both inputs and observe the waveform.

Next, disconnect both inputs at the chassis. Connect the vertical input of the scope to the plate, pin 5, V2B (A-8R) and adjust its deflection to the same amplitude as the others. Reconnect the horizontal input to pin 6, V2B (A-6L) and observe the waveform.

REVIEW AND SUMMARY

In this topic you have studied the general purpose oscilloscope. The principal points you should have learned are listed below:

1. How the horizontal sweep circuit causes the beam to sweep across the face of the CRT.
2. How the sweep time is controlled either internally or by an external trigger.
3. Recognition of the OS-8E/U.
4. Use of probes with the scope.
5. How Lissajous patterns are developed and how to interpret them.
6. The use of the graticule for amplitude and time measurement of waveforms.



60. OSCILLOSCOPE, SIGNAL FLOW BLOCK DIAGRAM

TOPIC 3: SYNCHROSCOPE AN/USM-32

You Are Now Going to Learn:

1. What a synchroscope is.
2. The Synchroscope AN/USM-32 controls.
3. Functional data flow in the AN/USM-32.
4. Use of special circuitry in a synchroscope.

Discussion Points for this Topic Are:

1. Introduction.
2. Panel controls.
3. Functional description.
4. Review and summary.

INFORMATION AND DISCUSSION:

INTRODUCTION

This topic has been included in this Trainee's Guide for information. You will not use the AN/USM-32 in this course. However it is probable that aboard ship the 32 will be found and used quite frequently.

Throughout this discussion you should note the similarity between this synchroscope and the OS-8E/U. The new circuitry presented will be easy to understand now that you have learned one scope construction, function, and operation. Particularly, the discussion on operation will be useful to you later as an operator's guide for this scope use.

You will find also, that an understanding of the material in this topic will serve as a background for the topics to follow. Topic 4 will cover the Synchroscope AN/USM-117, a transistorized scope that you will use frequently in the remainder of this school.

The Synchroscope AN/USM-32 is more refined than any of the scopes you have used thus far. An oscilloscope that has a sweep of very short time duration, generated only when a synchronizing signal is provided, is called a SYNCHROSCOPE.

PANEL CONTROLS

To familiarize yourselves with the 32 you will now study the panel controls. A list of the controls and their functions follows:

1. BRIGHTNESS — control for adjusting brilliance of trace.

2. FOCUS — control to adjust for maximum sharpness of trace.

3. & 4. HOR GAIN — concentric controls; outer knob, HORizontal GAIN, provides horizontal expansion of sweep trace; Inner knob, HORizontal POSition, provides horizontal positioning of trace.

5. & 6. SWEEP TIME — concentric controls; outer knob, SWEEP TIME (COARSE), provides step adjustment of sweep duration; Inner knob, SWEEP TIME (FINE), provides continuous control of sweep duration within limits established by SWEEP TIME (COARSE) setting.

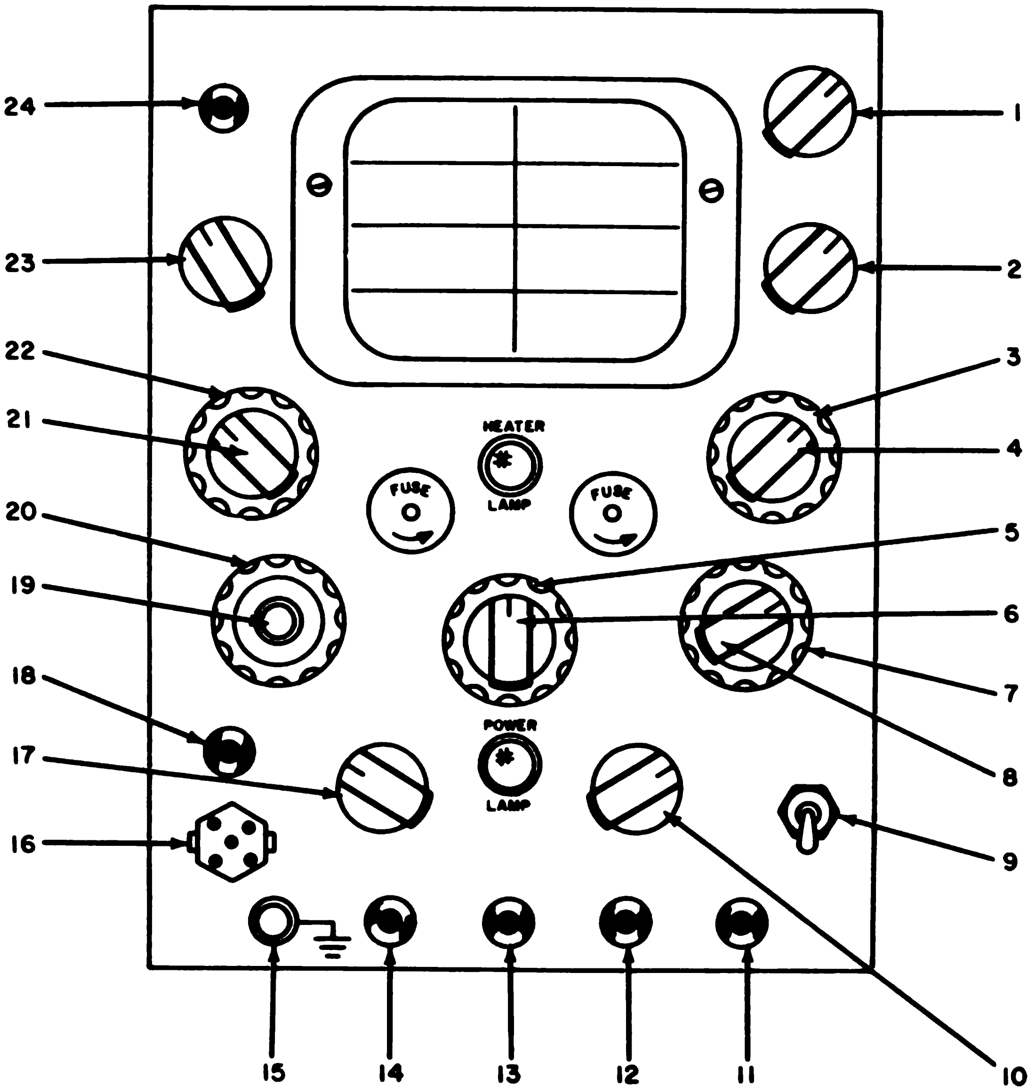
7. & 8. SYNCHRONIZATION — concentric controls; outer knob selects source and polarity of sweep initiating signal from TRIGger, power LINE frequency, EXternal signal, EXternal attenuated 15:1, and vertical amplifier; inner knob continuously controls sync amplitude.

9. POWER ON-HEATER ON — toggle switch; for applying primary power for operation of either the instrument or the space heater.

10. MARKER INTERVAL — control switch for selection of internal timing markers or external timing signals, as desired.

11. SYNC IN — coaxial terminal jack; for connecting external sweep initiating signals, 1 meg, 45 $\mu\mu$f (EX) 1.5 meg, 10 $\mu\mu$f (EX/15).

12. MARK OUT; Z IN — coaxial terminal jack; dual function as selected by MARKER INTERVAL switch-(1) supplies intensity markers for external use or (2) provides input connection for external timing signals.



61. AN/USM-32, FRONT PANEL CONTROLS

13. CAL OUT; 0. 6 VPP — coaxial terminal jack; supplies CALibration OUTput of 0. 6 volt peak-to-peak for external use.

14. +TRIG OUT — coaxial terminal jack; supplies positive trigger pulses of approx. 100 v for external use at a repetition rate determined by setting of TRIGGER RATE control.

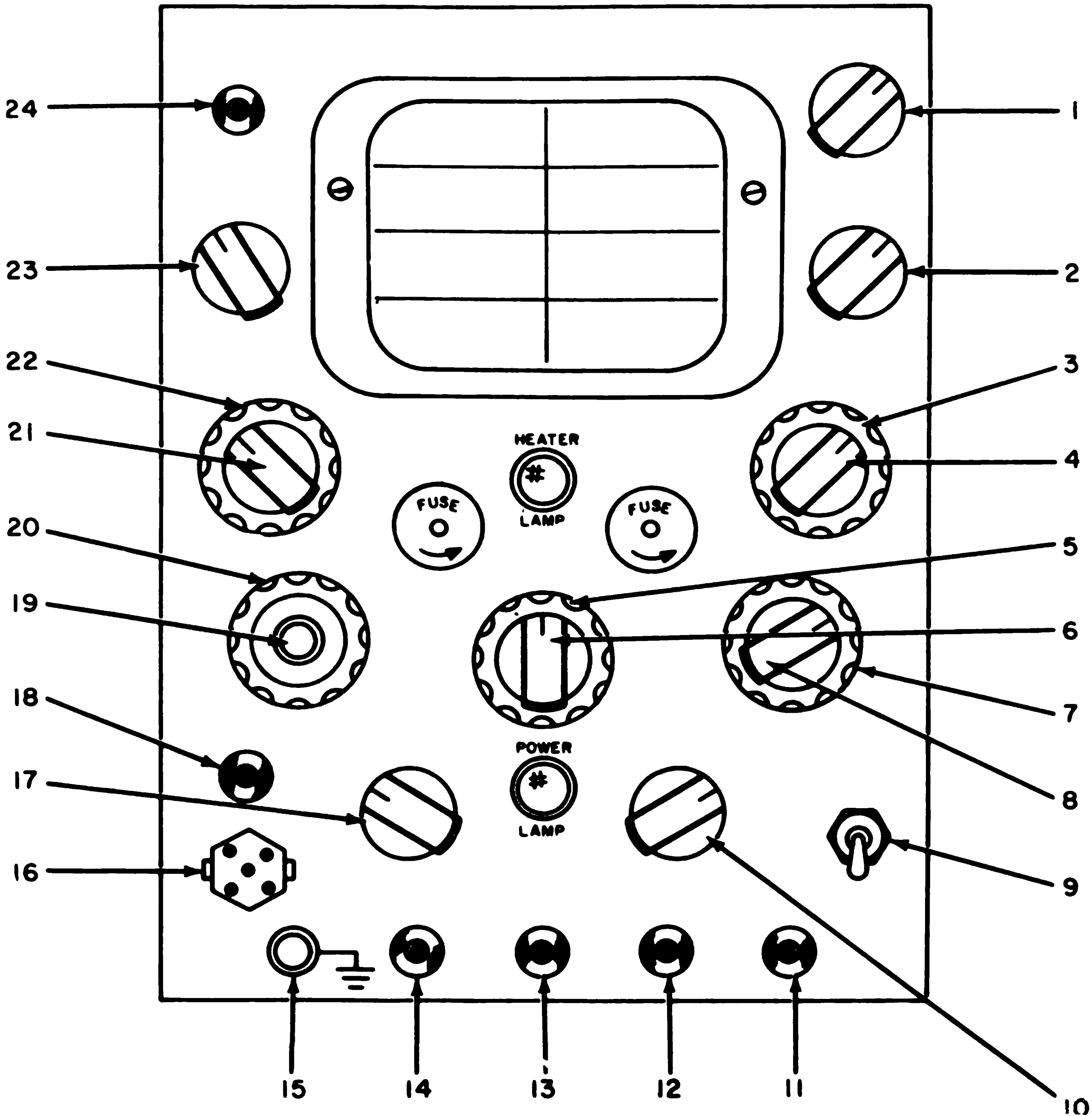
15. GND — binding post terminal; provides a connection for grounding the instrument.

16. C. F. PROBE — terminal socket; dual function of connection of (1) cathode follower PROBE or (2) 75 ohm TERMINATION for the VERTical SIGnal.

17. TRIGGER RATE — control with switch; ON-OFF switch operates internal trigger generator. TRIGGER RATE control provides continuous adjustment of repetition rate.

18. VERT SIG — coaxial terminal jack; for connection of input signal to vertical amplifier. Impedance 1 meg, 28 $\mu\mu$f.

19. & 20. PRESS TO CAL, VOLTS PER INCH — concentric switches; outer knob, volts per inch, provides accurate, ratio step



62. AN/USM-32, FRONT PANEL CONTROLS

attenuation of input signal: inner button, PRESS TO CALibrate, used in conjunction with VERTical GAIN for amplifier calibration. Set to 2" for indicated sensitivities.

21. & 22. VERT POS, VERT GAIN — concentric controls; outer knob, VERTical GAIN, provides continuous amplitude adjustment of vertical deflection. (Also used to set vertical amplifier to known sensitivity for amplitude calibration); inner knob VERTical POSition provides vertical positioning of trace.

23. VERT DIRECT-AMP — control switch; for selection of "through vertical amplifier" or "direct to deflection plate" connection of input signal.

24. VERT DIRECT — coaxial terminal jack; for connection of input signal through a capacitor direct to a deflection plate 3 meg, 30 $\mu\mu f$.

FUNCTIONAL DESCRIPTION

Before using the AN/USM-32 it will be to your advantage to understand the overall operation and internal signal flow of the scope. Refer to the foldout block diagram at the end of this topic for location of the items under discussion.

The vertical signal can be applied to the scope in one of three different ways. If the signal is applied to the VERT. DIRECT jack and the VERT. DIRECT AMP switch is in the DIRECT position, the signal is applied directly to the vertical plate of the CRT. If the signal is applied to the VERT. SIG. jack with the VOLTS-PER-INCH switch in the CF PROBE position and the CF PROBE plugged in, the signal bypasses the vertical attenuator but goes through the amplifier. The normal input is to the VERT. SIG. jack with the VOLTS-PER-INCH switch in one of the attenuator positions. In this case the signal is attenuated and then sent to the vertical amplifier. The VERTICAL GAIN control is in this circuit. After the first amplification, a portion of the signal is sent back to the sync circuits to aid in synchronizing the sweep. The signal is also sent to the delay line where it is delayed slightly to allow the sweep to start before the signal is applied to the sweep. From the delay line, the signal is sent to the vert. deflection amplifier where it is further amplified and inverted to produce two signals 180 degrees out of phase to be applied to the vertical plates of the CRT. The VERTICAL POSITION control is in the final stage.

Also incorporated in the vertical section is the voltage calibrator. This circuit provides a calibrated 0.6 v peak-to-peak 60 cycle square wave voltage for calibration of the scope when the PRESS-TO-CAL. button is pushed in. This same voltage is available for external use at the CAL. OUT jack. It also sent to the SYNC SELECTOR switch for synchronization of the sweep when the switch is in the LINE position.

The horizontal section actually originates at the sync circuit. The sync circuit may be triggered from four sources either positively or negatively depending upon the position of the SYNC SELECTOR switch. When this switch is in the V position, the trigger is fed back from the vertical amplifier. When the switch is in the LINE position the trigger is supplied by the 0.6 V peak-to-peak square wave from the voltage calibrator. When the switch is in the EX position, the trigger may be applied from an external source connected to the SYNC IN jack. This external signal may also be attenuated 15:1 by setting the SYNC SELECTOR switch to EX/15. When the SYNC SELECTOR switch is in the TRIG position the trigger is applied from the Trigger Generator. The frequency of the trigger can be varied from 45 cps to 5500 cps by rotation of the TRIGGER RATE CONTROL switch in the Trigger Generator circuit. This trigger is also available at the TRIGGER OUT jack for external use.

After the desired trigger has been applied to the sync circuit, the amplitude of this signal can be controlled by the SYNC GAIN control. The signal is then coupled, either negatively or positively, depending on the setting of the SYNC SELECTOR switch, to the Gate Generator.

The Gate Generator is a multivibrator which provides a square wave when triggered. This square wave is used to trigger the three circuits that follow it. These are the Sweep Generator, Gate Shaper and the Time Mark Generator. We will discuss these circuits separately.

The Sweep Generator, when triggered by the Gate Generator, initiates a sawtooth voltage. The frequency of the sawtooth is controlled by the setting of the COARSE and FINE SWEEP TIME control. The output of the Sweep Generator is coupled to the Sweep Deflection Amplifier where it is amplified and inverted to provide two sawtooth voltages 180 degrees out of phase, to apply to the horizontal plates of the CRT. The HORIZONTAL GAIN and HORIZONTAL POSITION controls are also in this final stage.

The square wave signal applied to the Gate Shaper is reshaped and applied to the control grid of the CRT as unblanking voltages. The CRT is normally in a cut-off condition and therefore must be unblanked during sweep time.

The square wave signal applied to the Time Mark Generator activates an extremely accurate oscillator. The output of this oscillator is shaped into pulses at very accurate time intervals in microseconds of 1, 10, 100, 1,000, or 10,000 determined by the setting of the MARKER INTERVAL control. When the MARKER INTERVAL control is in any of these positions, the markers are sent to the Beam Modulation Amplifier and are also available at the MARK OUT-Z IN jack for external use. The Beam Modulation Amplifier, after amplifying the markers, sends them to the cathode of the CRT where they are applied as positive spikes to cut the CRT off each time a marker is applied. These markers will then appear as dark spots on the sweep. The intervals between the dark spots are a definite number of microseconds wide depending on the setting of the MARKER INTERVAL switch.

Another possible input to the Beam Modulation Amplifier can be accomplished by setting the MARKER INTERVAL switch to Z IN. In this position an external marker can be applied at the MARK OUT-Z IN jack to provide the markers on the scope. A positive 10 volt peak pulse will provide blanking or dark spots on the sweep. A negative 10 volts peak pulse will provide bright spots on the sweep. When using the Z IN marker the scope sweep must by synchronized externally to the frequency of the Z IN signal.

Included in the scope is a space heater that may be used to keep the scope warm when it is not actually being used. This is accomplished by setting the power switch to the Heater On position.

The scope contains its own high and low DC voltage and AC voltage power supplies that are necessary for operation when 115 VAC single phase, 60 cycle power is applied and the power switch is in the POWER ON position.

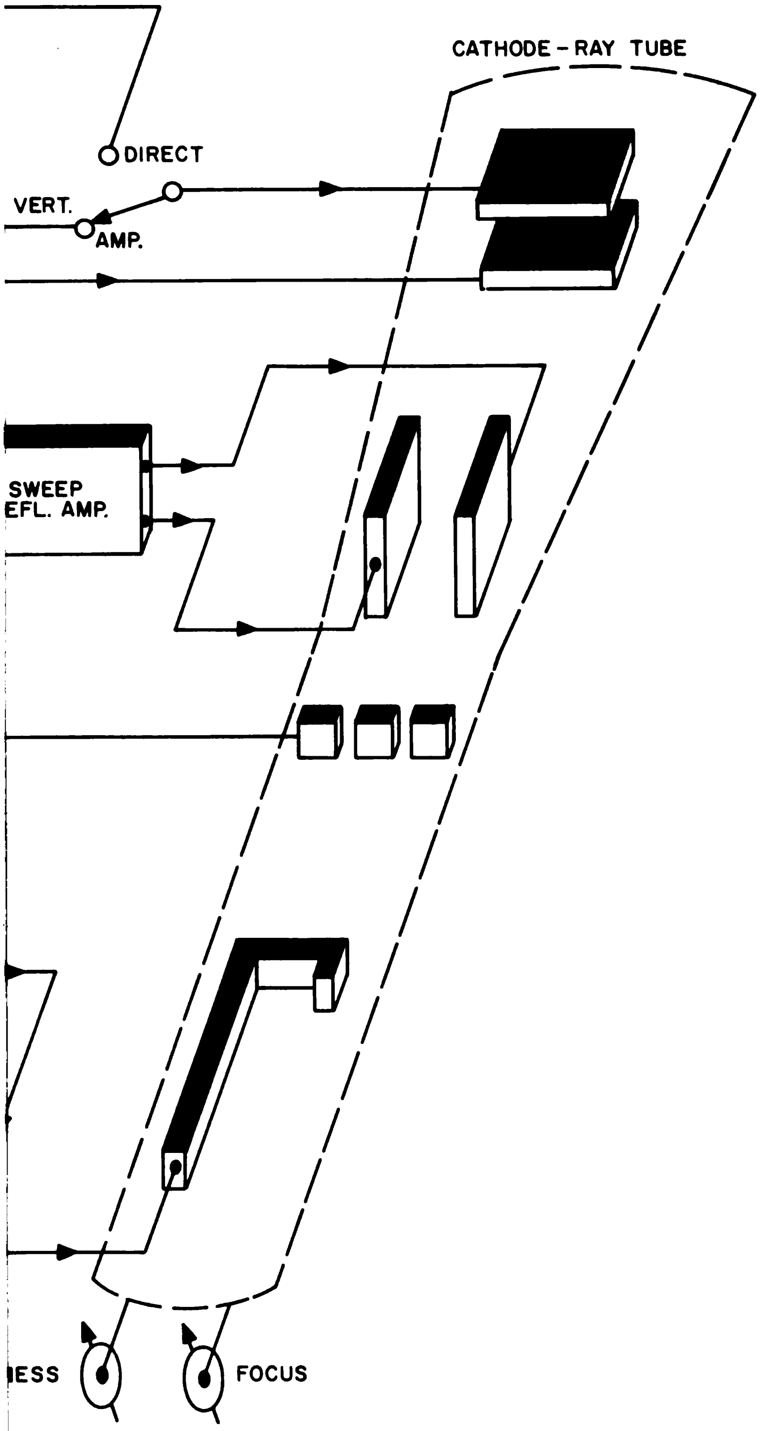
Information on theory, operation, care, and maintenance of the AN/USM-32 is contained in INSTRUCTION BOOK, NAVSHIPS 92257.

REVIEW AND SUMMARY

In this topic you have learned the use of the more advanced type oscilloscope, commonly called synchroscope.

You have learned:

1. The names and functions of the front panel controls of the AN/USM-32.
2. How the synchroscope differs from the general purpose oscilloscope, the additional circuits, functions and capabilities of the AN/USM-32.
3. Where a synchroscope can be used to advantage.
4. Operation and purpose of the Time Mark Generator and Beam Modulation Amplifier.
5. How to use the AN/USM-32 for pulse width and amplitude measurements and for making adjustments of pulse circuits.



/USM-32 SYNCHROSCOPE, FUNCTIONAL BLOCK DIAGRAM

TOPIC 4: SYNCHROSCOPE AN/USM-117

You Are Now Going to Learn:

1. The operation of an advanced oscilloscope.
2. The advantages of advanced scope design.
3. Functional data flow in the AN/USM-117.

You Will Acquire Skill in:

1. The use of an advanced oscilloscope.
2. The use of the low capacitance probe in signal tracing.

Discussion Points for this Topic Are:

1. Introduction.
2. Panel controls.
3. Description.
4. Functional operation.
5. Dual trace preamplifier.
6. Experiments.
7. Review and summary.

INFORMATION AND DISCUSSION:

INTRODUCTION

By now you can appreciate the usefulness of the oscilloscope in maintenance. As stated elsewhere in this text, all oscilloscopes are basically of the same general design and use the same principles of operation. The synchroscope that you are to work with now, the AN/USM-117, is no exception. The discussion to follow in this topic will illustrate these points.

The experiments that you will perform with the 117 will be familiar in nature and are designed to show you the advantages of the newer scopes. The techniques utilized in these experiments and performance tests using the 117 are the real measure of your achievement in the use of test equipment.

The Synchroscope AN/USM-117 is a compact, transistorized, portable oscilloscope that the technician may use for most of his preventive and corrective maintenance. A special feature of this scope is its plug-in units for its vertical deflection circuits. One of the plug-in units provides dual trace capabilities while the other is single-channel. Sine wave signals up to nearly five megacycles in frequency can be measured and observed with this oscilloscope.

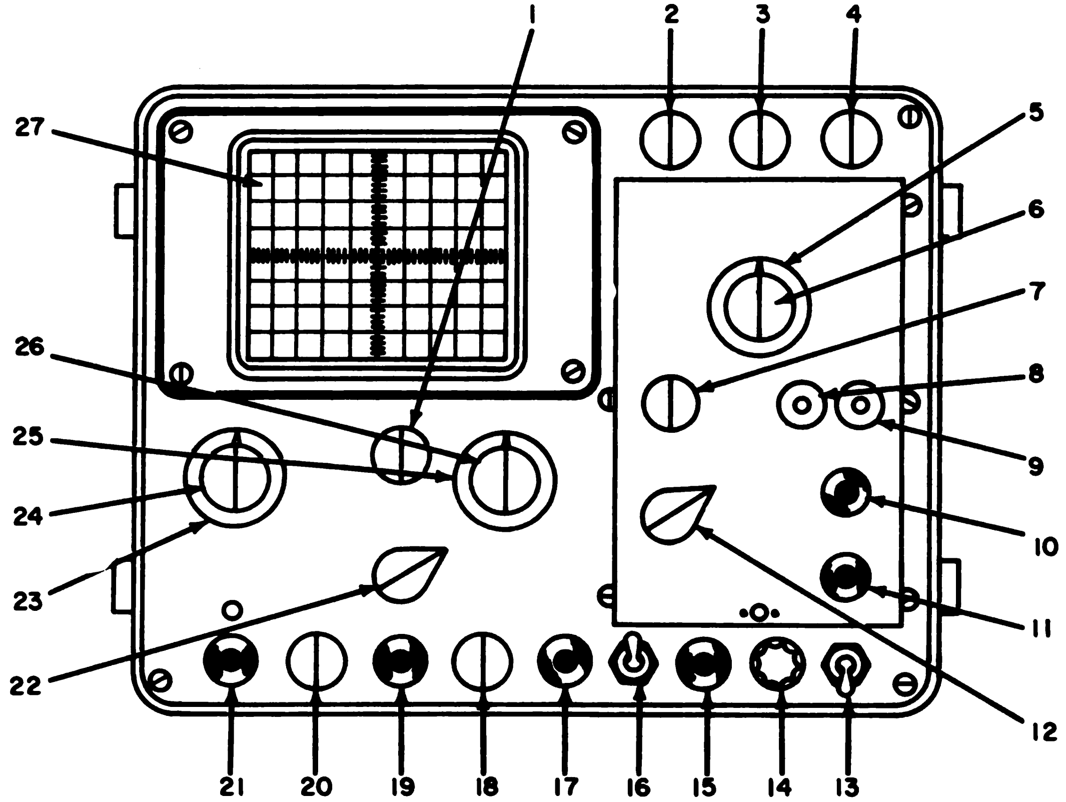
The display consists of a calibrated horizontal time base sweep and a calibrated vertical deflection system. Along with a graticule, these features make this scope a precision instrument. Horizontal frequency is selected in units of TIME/DIV and voltage as VOLTS/DIV, hence frequency determination and measurement of voltage are accomplished rapidly and accurately.

Low capacitance probes are provided as scope accessories, insuring minimum loading of the circuit under test by the scope.

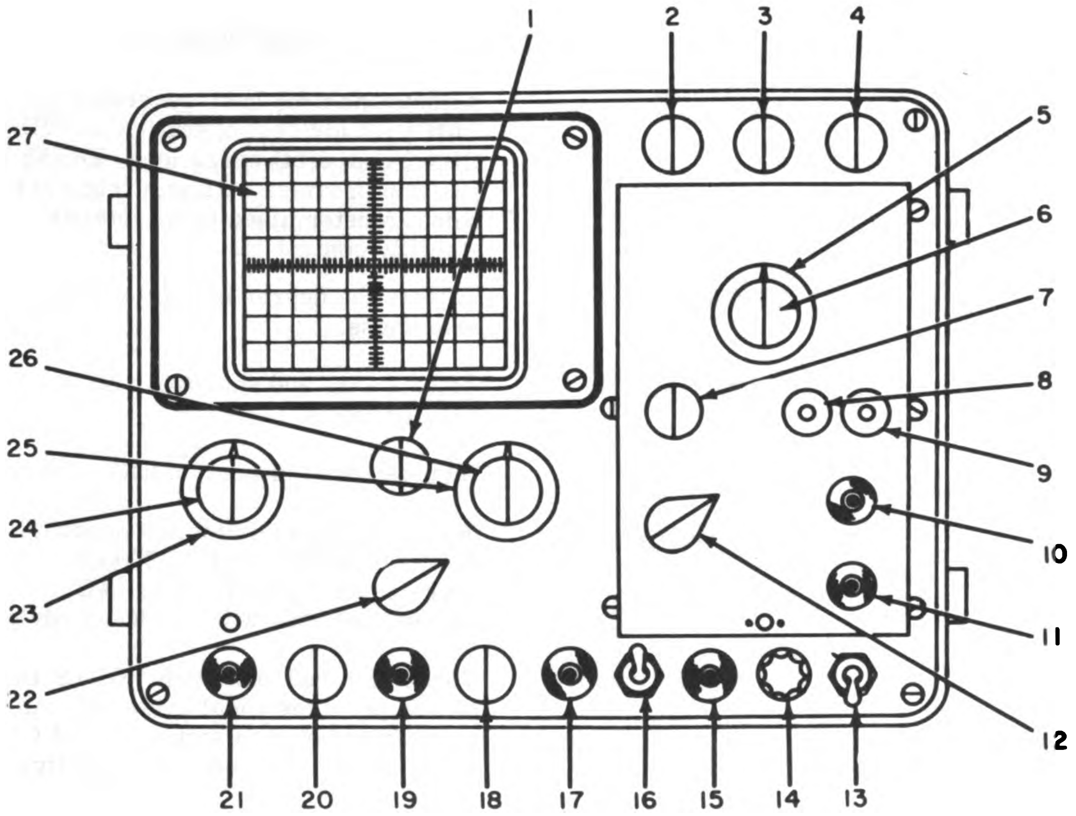
PANEL CONTROLS

The next few pages will familiarize you with the names of the scope controls, their location and their purpose.

NO.	NAME	FUNCTION
1	STABILITY	Adjusts the time base generator for TRIGGER (driven) operation or FREE RUN (recurrent) operation. PRESET position provides optimum triggering point as determined by an internal stability control.
2	INTENSITY	Adjusts the degree of spot or trace brightness.
3	FOCUS	Adjusts size and sharpness of spot on CRT screen.
4	ASTIG	Adjusts shape of spot on CRT screen.
5	VOLTS/DIV switch	Selects Vertical deflection sensitivity values from 0.01 volt to 20 volts peak-to-peak per division. AC coupled only below 0.1 volt per division.
6	VARIABLE control	Concentric red knob with VOLTS/DIV switch provides uncalibrated variable sensitivity between steps on the VOLTS/DIV switch. Also extends sensitivity



64. AN/USM-117, FRONT PANEL CONTROLS



65. AN/USM-117, FRONT PANEL CONTROLS

		on 20 VOLTS/DIV range to 50 VOLTS/DIV.
7	POSITION control	Positions the trace on a vertical plane.
8	DC BAL control	Adjusts balance of vertical preamplifier, thereby preventing trace shift when the variable control is rotated.
9	EF BAL control	Adjusts input impedance of input stage to proper value, and prevents trace shift when VOLTS/DIV switch is rotated.
10	INPUT A connector	Accepts signals fed to vertical preamplifier.
11	INPUT B connector	Accepts signals fed to vertical preamplifier.
12	INPUT SELECTOR switch	Selects either INPUT A or INPUT B with AC or DC coupling as desired.
13	POWER switch	Turns power on or off.
14	SCALE control	Adjusts illumination of lines on the CRT graticule.

15	CALIBRATOR OUTPUT	Provides accurate square wave of either 0.04 or 0.4 volts, P-P, as determined by the setting of the CALIBRATOR switch.
16	CALIBRATOR switch	Selects accurate square wave of either 0.04 or 0.4 volts, P-P, Output waveform is available at front panel jack.
17	EXT TRIGGER INPUT connector	Accepts signals to trigger the sweep when the TRIGGER SLOPE switch is set to any position on the right hand side of its dial.
18	POSITION control	Positions the trace on a horizontal plane.
19	HORIZONTAL INPUT connector	Accepts signals for horizontal deflection when the HORIZONTAL MODE switch is set to X1, X2 or X5.
20	HORIZONTAL GAIN control	Adjusts uncalibrated variable sensitivity between X1, X2 and X5b ranges. Also extends sensitivity on X5 range beyond five volts per division.
21	Z-AXIS INPUT connector	Accepts signals for intensity modulation of CRT.
22	HORIZONTAL MODE switch	Functions to attenuate external horizontal deflection waveforms on the X1, X2 and X5 positions. Also provides sweep and 5X MAG sweep.
23	TIME/DIV switch	Selects sweep speeds in 19 calibrated steps in a 1, 2, 5 or 10 sequence from 0.1 microsecond to 0.1 second per division.
24	VARIABLE control	Concentric red knob with TIME/DIV switch provides adjustment between steps on TIME/DIV switch. When turned from the maximum CW position, the sweep is uncalibrated.
25	TRIGGER SLOPE switch	Selects the type of triggering signal; LINE, INT, and EXT on either + or — slope. AC or DC coupling may be selected on EXT TRIGGER INPUT.
26	LEVEL control	Concentric red knob with TRIGGER SLOPE switch determines the level of the amplitude of the triggering waveform for the start of the sweep.
27	GRATICULE	Edge illuminated type, 10 divisions long by 8 div. high. (1 division equals 1/4 in.)

DESCRIPTION

The complete set of operating instructions for the 117 are found in NAVSHIPS 94344(A) and NAVSHIPS 95712, the technical manuals for the oscilloscope and the dual trace preamplifier. The next two paragraphs are a discussion of the scope probes.

Two test probes MX-2817/U are supplied with each USM 117. When circuit loading would be detrimental to the circuit under test, these low-capacitance probes are used. Using the probes affords ten times the normal input resistance and a much lower shunt capacitance, (10 megs, 13pf). Sensitivity figures read from the VOLTS/DIV SWITCH dial should be multiplied by ten when these probes are used. For example, 0.1 VOLTS/DIV would become 1.0 VOLTS/DIV.

Frequency compensation of the probe should be checked before use. The 0.4 volt square wave output of the CALIBRATOR may be used for this check. Set the VOLTS/DIV switch to 0.1 and the TIME/DIV switch to 0.2 millisecs. Touch the tip of the probe to the CALIBRATOR output connector. Adjust the STABILITY and LEVEL controls to obtain a stable waveform pattern. Back off on the locking ring at the rear section of the probe and rotate the disc-like adjustment that was held tight by the locking ring. Adjust the probe for optimum square wave response; no overshoot or undershoot. Once the response is correct, tighten the locking ring to hold this adjustment. The probe is now properly compensated.

CAUTION

> In tightening the locking ring, it is possible that the adjustment will be upset slightly. Check for this and tighten the locking ring accordingly.

FUNCTIONAL OPERATION

This next discussion will be of the signal flow through the scope circuitry. At the end of this topic there is a fold-out of the 117 block diagram. Refer to it as you read the following paragraphs.

The signal flow starts with a signal being applied to the test probe. Let us take the .4V P-P output of the scope's calibrator as a signal to INPUT A, thus the INPUT SELECTOR must be in position A for the square wave to reach the VOLTS/DIV switch. The VOLTS/DIV switch has eleven positions ranging from .01 Volt to .05 Volt (P-P)/DIV AC and .1 to 20 Volt P-P AC or DC. One of the eleven attenuator networks is selected and the square wave is now applied to the preamplifier. The several stages of paraphase amplifiers produce a balanced push-pull output. (Two signals, 180 degrees out-of-phase, of equal amplitude.) The above circuits are all contained in a high gain plug-in preamplifier.

The balanced push-pull square wave signal is now applied to the delay lines of the vertical amp section. These delay lines cause a delay in time of the start of the balanced push-pull signal. This delay insures that the horizontal time base starts before the signal, when the internal trigger is used. The entire signal may be observed on the CRT under this selected condition.

The square wave signals are next applied to the vertical amplifier stages. These push-pull amplifiers enlarge the voltages sufficiently to cause CRT beam deflection and are applied to the vertical deflection plates. The gain of the vertical amplifier is of a fixed value when the VARIABLE control is turned maximum clockwise to the calibrate position. That is to say, that the vertical channel is calibrated at that setting of the VOLTS/DIV control dial.

Observe the input signals to the vertical amplifier again and notice that one signal, before going to the delay line, is also coupled to the internal trigger amplifier. This signal after being amplified, is in phase with the original square wave at the test probe. It is sent to the TRIGGER SLOPE switch which has four positions. These are: INT (internal), LINE, EXT-AC(external), and EXT-DC. A selection of positive or negative slope triggering can be made for each position. The selected trigger is sent to the trigger amplifier and is then coupled to the sweep multivibrator as its trigger. One output of the driven sweep MV is applied to the unblanking circuits. The unblanking circuits apply a positive square wave to the control grid to increase beam intensity for the time occurence of the horizontal sweep. The other output of the sweep MV is coupled to the sweep generator. The sweep generator develops a linear sawtooth waveform of a constant amplitude.

The RC time network controlling the rise time of the sawtooth waveform is selected by the TIME/DIV switch. Any one of the nineteen calibrated sweep speeds can be selected when the VARIABLE control is maximum clockwise. The nineteen TIME/DIV selections range from .1 microsec/div to .1 sec/div.

The selected sweep rate sawtooth waveform is sent from the TIME/DIV switch to the horizontal amplifier. The horizontal amplifier inverts and amplifies the single sawtooth waveform, thus balanced push-pull sawtooth waveforms are used to drive the horizontal deflection plates of the CRT.

It is possible to apply an external signal directly to the horizontal amplifier through the HORIZONTAL MODE switch. The HOR. MODE switch also provides a 5X magnification factor in the calibrated position. The 5X magnification adds microscopic precision to the synchroscope.

The calibrator shown provides two calibrated square wave outputs for external use. The .4 Volt P-P or .04 Volt P-P output can be selected with the CALIBRATION switch. The CALIBRATOR ON-OFF switch allows it to be off when not in use.

The .4 Volt P-P output of the calibrator was used as a signal input in the block diagram. With the VOLTS/DIV switch to .1 position and VARIABLE control maximum CW, the CRT display should be a square wave having a P-P amplitude of 4 divisions. This illustrates a check of the gain of the vertical amplifier section. Remember that if the low-capacitance probe is used for these operations that the 10:1 attenuation factor must be considered.

If the output of the calibrator were 1000 cycles/sec and .2 millisec/div is selected in the CALIBRATE position, the period of the square wave will extend over 5 divisions horizontally.

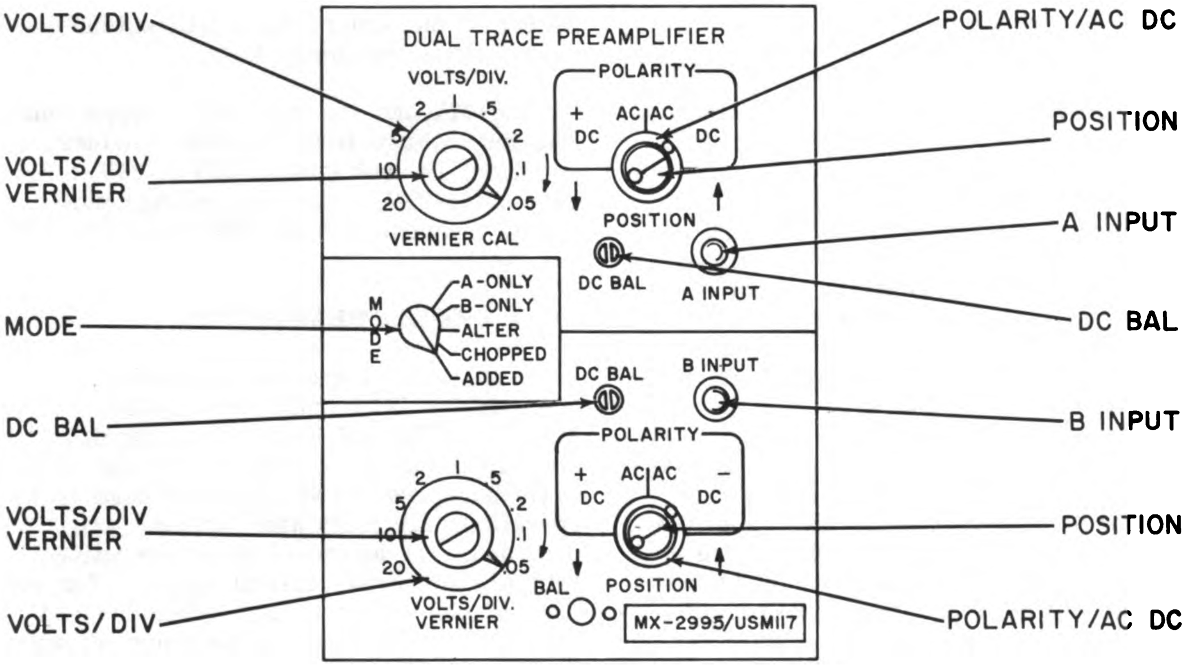
The 117 has its own power supply unit. The low voltage power supply provides regulated DC voltages of 55V, -15V, -5V, +5V, and +20V. The high voltage power supply provides a 2400 VDC and -580 VDC for the CRT.

DUAL TRACE PREAMPLIFIER

Each vertical channel preamplifier stage in the Dual trace Preamplifier MX-2995/USM-117 has a 50 millivolt/division basic sensitivity with a five megacycle bandpass. Two modes of dual trace operation, alternate and chopped, are provided: (1) alternate mode operation switches the first vertical input on for the time of one sweep cycle. After the end of this sweep cycle it is switched off and the second vertical input signal is switched on for the following or alternate scan. The process is continuously repeated, displaying each waveform in alternate turns on screen. At faster sweep rates a dual display effect is produced because of CRT screen persistence. (2) in chopped mode operation, a dual display is created by switching between the two vertical input signals at a 100 kc rate, and presenting this dual information or composite switching signal on each sweep cycle. At slower sweep rates the trace segments caused by switching blend together to faithfully reproduce each waveform.

When the A ONLY and B ONLY modes are used, operation is limited to single channel. The dual trace switching circuits are used to switch on just the desired channel. ADDED mode operation algebraically combines the two vertical input signals by switching on both channels.

Dual displays afford accurate time measurement between two waveforms. Accurate amplitude comparisons may also be made. Both vertical channel preamplifier stages are identical in circuit configuration and physical layout, thereby reducing any phase error.



66. DUAL TRACE PREAMPLIFIER, FRONT VIEW

The illustration above shows the front of the dual trace preamp.

Experiments 3-4-1, Checking Voltage Calibration

The 117 provides a highly accurate calibrated square wave output at the CALIBRATOR jack of either .04 or .4 volts P-P to be used for voltage calibration of equipment. It can also be used to check the accuracy of the settings of the VOLTS/DIV switch.

To accomplish this, connect a lead from the calibrator output (15) to INPUT A. Set the VOLTS/DIV switch to .01 and the variable VOLTS/DIV control maximum clockwise. Set the CALIBRATOR switch to .04. The square wave on the scope should be exactly 4 squares high ± 5%. Set the VOLTS/DIV switch to .02. The square wave should now be 2 squares high.

Set the VOLTS/DIV switch to .1 and the CALIBRATOR switch to .4. The square wave should be 4 squares high. Set the VOLTS/DIV switch to .02. The square wave should now be 2 squares high.

If these checks result in proper readings, the scope voltage reading can be considered as accurate; if not, the scope must be recalibrated and adjusted. These adjustments must be made only by experienced personnel according to directions in NAVSHIPS 94344(A).

Experiments 3-4-2, Frequency and Voltage Measurement

Waveforms can be observed, the frequency determined, and the voltage amplitudes measured in one operation using the 117.

The method of determining the frequency, used in this experiment, is to measure the period of one cycle and calculate the frequency by use of the formula $f = 1/P$. This is an accurate and widely used method.

The horizontal sweep of the 117 is calibrated to represent an exact time in microseconds or milliseconds. Shown at bottom of this page, the horizontal sweep is adjusted so that each square on the graticule is equal to .2 milliseconds. One cycle of the input waveform covers 5 squares, thus $5 \times .2 \times 10^{-3} = .001$ sec, or 1 millisecond. This is the PERIOD of one cycle. The frequency equals 1/P or 1000 cps. The accuracy of the CALIBRATOR output is checked in this manner. Before continuing with this experiment, check the CALIBRATOR output frequency.

The next step in this experiment is to measure the frequency of the Wien bridge oscillator in the Special circuits chassis.

To connect a signal from the Wien bridge oscillator to the scope, connect an adapter UG-1035/U to INPUT A jack. This adapter allows the use of ordinary test leads for connecting the signal. Set the INPUT selector switch INPUT A AC. Set the VOLTS/DIV switch to 20. Connect a test lead from the red side of the adapter to the plate (pin 5) of V2B (A-8R). Connect a test lead from the black side of the adapter to chassis ground.

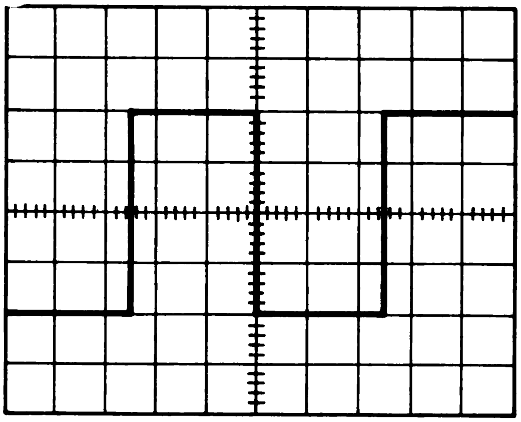
To apply external synchronization, connect another adapter UG-1035/U to the EXTERNAL TRIGGER jack. Connect the red side of the adapter to the cathode (pin 6) of V2B (A-6L) and black side to chassis ground. Set the TRIGGER SLOPE switch to +AC.

A signal waveform should now be visible on the scope. Set the TIME/DIV switch to .2 millisec. Turn the VARIABLE TIME/DIV control maximum clockwise. The sweep is now calibrated to equal .2 millisec for each horizontal square on the graticule. Adjust the STABILITY and LEVEL controls as necessary to stabilize the signal. (Note: It may be necessary to adjust the Wien bridge oscillator to obtain a good sine wave output.) Count the number of squares one cycle covers (X-axis).

Multiply the number of squares that one cycle covers by .2. This is the PERIOD expressed in millisecs. Divide 1000 by the product obtained above; the quotient is the frequency in cps of the Wien bridge.

> NOTE: Do not move the VARIABLE TIME/DIV control as this will cause the sweep to lose calibration.

Find the peak-to-peak voltage of the Wien bridge output. Set the VOLTS/DIV control to 10. Set the VARIABLE VOLTS/DIV maximum clockwise. The scope is now calibrated for 10 V (P-P) for each vertical square. Adjust the vertical POSITION control to place the lower extremity of the sine wave exactly on a horizontal line. Adjust the horizontal POSITION control to place the top of the sine wave exactly on the center vertical line of the graticule. Count the number of squares the sine wave covers vertically, multiply this number by 10 V (P-P) to obtain the P-P voltage of the sine wave. Dividing by 2 gives the peak voltage. Peak voltage times .707 gives RMS (effective) voltage. (Note: Do not move the VARIABLE VOLTS/DIV control as this will change the calibration.)


SWEEP CALIBRATION: .2ms/DIV
VERT CALIBRATION: .1V P-P/DIV

67. CALIBRATOR OUTPUT

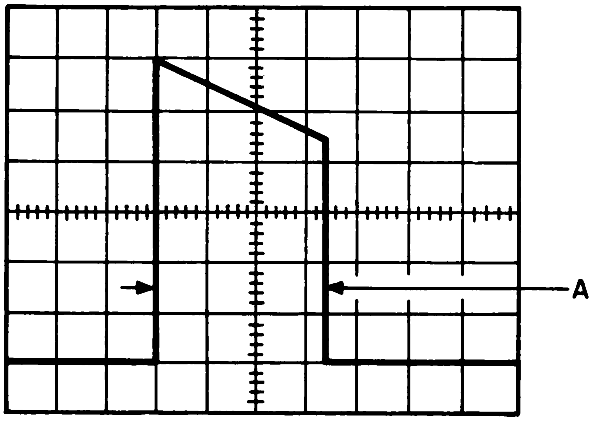
Experiments 3-4-3, Measuring Pulse Width and Amplitude

Many times while troubleshooting radar equipment, it becomes necessary to determine the width of a pulse in microseconds and the amplitude of the waveform. To illustrate how this can be accomplished with the 117, you will measure the width and amplitude of the output pulse at the cathode of the Blocking oscillator.

Set the 117 as follows. Connect the red side of the EXTERNAL TRIGGER jack adapter to the cathode pin 6 of V6B (A-26L). Connect the black sides of both adapters to chassis ground. Adjust the scope controls for a waveform similar to that shown below.

You may now measure the width of the pulse along line A. To accomplish this, set the TIME/DIV control to .1 milliseconds. Set the VARIABLE TIME/DIV control maximum clockwise. The sweep is now calibrated for .1 milliseconds or 100 microseconds for each horizontal square. Adjust the VERTICAL POSITION control so that the top of the trailing edge of the waveform is on the horizontal axis. Determine the number of horizontal squares that time A covers on the axis. The width in microseconds can be determined by multiplying this figure times 100 microseconds.

Assume that time A covers 3.4 squares. The width of the pulse at time A then is 3.4 times 100 or 340 microseconds. Using this procedure, determine the width of your Blocking oscillator pulse.



68. BLOCKING OSCILLATOR OUTPUT

Next you will check the amplitude of the leading edge of the pulse. To accomplish this, set the VOLTS/DIV switch on 20, and set the VARIABLE VOLTS/DIV control maximum clockwise and leave it there. Adjust the VERTICAL POSITION control so that the bottom of the pulse is on the lower horizontal line. Adjust the HORIZONTAL POSITION control so the top of the leading edge is on the vertical axis.

Count the number of squares that the leading edge covers vertically. Multiply this times the setting of the VOLTS/DIV switch to determine the amplitude. Assuming that the leading edge covers 6 squares, the amplitude would be 6 times 20 or 120 volts. Using this procedure, measure the amplitude of both the leading and trailing edges of the pulse and make a comparison. By analyzing these readings you can determine that this pulse is being generated properly.

Experiments 3-4-4, Using Lissajous Patterns

The 117 is very easily adapted for using Lissajous patterns. It requires only the setting of the HORIZONTAL MODE switch to the X1, X2, or X5 position, depending on the amplitude of the input, and connecting the horizontal input signal to the HORIZONTAL INPUT jack (19) through the UG-1035/U adapter. The horizontal gain can also be controlled with the HORIZONTAL GAIN adjust (20).

Set the VOLTS/DIV switch at 20 and apply the output of the Wien bridge oscillator to the INPUT A jack on the scope. Connect the 6.3 VAC filament supply from terminal 6 and 8 of T1 (chassis) to the HORIZONTAL INPUT jack (19), through UG-1035/U.

Set the HORIZONTAL MODE switch to X1. Set the HORIZONTAL GAIN control so the signal is about 8 squares wide. Adjust R4 (on chassis) until the signal stops or rotates very slowly. Count the number of loops horizontally. There should be approximately 12. There should be one loop vertically. Since the one vertical loop is caused by a 60 cps signal and the ratio of loops is 1:12, the approximate frequency of the Wien bridge oscillator can be determined by multiplying 60 x 12. The frequency in this case is 720 cps.

Use this procedure and check the frequency of your Wien bridge oscillator.

Experiments 3-4-5, Balancing Adjustments for Dual Trace Preamplifier

Two sets of balancing adjustments are included in Dual trace Preamplifier MX-2995/USM-117 for proper operation. The DC BAL controls on the front panel adjust the input DC level of each channel to its proper value, thus preventing trace shift when the VOLTS/DIV switches are rotated. The AMPL BAL controls, R105 (for channel A) and R195 (for channel B), located inside the vertical plug-in, adjust balance of each channel and prevent trace shift when the VERNIER VOLTS/DIV controls are rotated. Therefore, unwanted trace shift indicates need for adjustment.

To make the balancing adjustments proceed as follows: insert vertical plug-in into plug-in compartment of the oscilloscope using the proper extension cable.

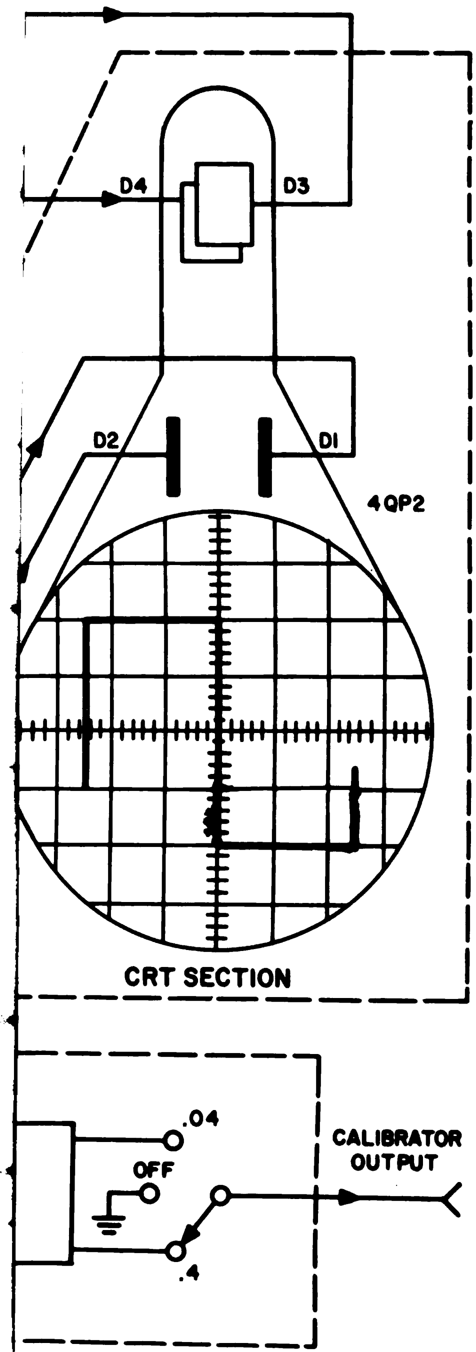
With no signal applied and the STABILITY control set to FREE RUN, rotate the VOLTS/DIV switch in each channel back and forth between the .05 and .1 positions. If a vertical deflection is noted on screen, adjust the DC BAL control for the channel in question until such deflection has ceased. Next, set the VOLTS/DIV switch of each channel to the .05 position and vary the VERNIER VOLTS/DIV control of each channel back and forth over its entire range. If any vertical deflection of the trace is noted on the screen, adjust the AMPL BAL control for the channel in question until such deflection has ceased. Since the adjustments for the DC BAL controls and AMPL BAL controls interact slightly, repeat this entire procedure for a finer adjustment.

REVIEW AND SUMMARY

In this topic you have studied the operation, capabilities, and uses of the Synchroscope AN/USM-117. The principal points that you learned are:

1. Names and functions of the front panel controls.
2. Signal flow from test probe to the deflection plates.
3. Horizontal sweep generation, calibration, and flow to the horizontal deflection plates.
4. Function and checking of the CALIBRATOR output.
5. Outputs of the scope power supply.
6. How to check voltage sensitivity.
7. How to measure voltage, frequency, and pulse width with the 117.
8. How to display Lissajous patterns.
9. How to make the balancing adjustments for the dual trace vertical preamplifier.

E, AN/ USM-117



9. AN/USM-117, BLOCK DIAGRAM

TOPIC 5: OSCILLOSCOPE, TEKTRONIX 545A

You Are Now Going to Learn:

1. The uses of the Tektronix scope.
2. The names and functions of the Tektronix panel controls.
3. Signal flow through the Tektronix 545A.

Discussion Points for this Topic Are:

1. Introduction.
2. Horizontal deflection.
3. Vertical deflection.
4. Time base generation.
5. Pulse analysis.
6. Experiment 3-5-1.
7. Review and summary.

INFORMATION AND DISCUSSION:

INTRODUCTION

This is the fourth and last oscilloscope that will be studied in this Trainee's Guide. This topic has been written to provide you with general information about the Oscilloscope, Tektronix 545A. There will be no practical application using this scope.

You are now well enough acquainted with oscilloscope usage and principles, that the following material will be familiar to you. Again, as stressed before, note the similarity of this scope design to that of the OS-8E/U and appreciate its innovations.

The Oscilloscope, Tektronix 545A is a wide range, general purpose, laboratory instrument. It provides accurate measurements in the DC to 30 MC. range and can be operated with any Tektronix letter series plug-in unit to satisfy the requirements for virtually any application.

For the following discussions, refer to the pullout drawing of the Tektronix 545A, block diagram at the end of this topic. The 545A provides two time bases (A and B) that can be used independently or in conjunction with each other. When used together they permit an accurate, continuously variable delay in the presentation of the sweep from one microsecond to ten seconds after receipt of a triggering pulse. This feature permits observation of a small portion of the normal sweep, accurate measurement of waveform jitter, and precise time measurement as well as many other uses.

HORIZONTAL DEFLECTION

The horizontal deflection system for Time Base A provides a sweep range of 0.1 microsecond to 5 seconds per centimeter in 24 accurately calibrated steps. An uncalibrated control permits the sweep rate to be varied continuously between 0.1 microsecond and approximately 12 seconds per centimeter.

The horizontal deflection system for Time Base B provides a sweep range of 2 microseconds to one second per centimeter in 18 accurately calibrated steps. A VARIABLE LENGTH control permits the sweep length to be varied from 4 cm to 10 cm (10 cm is maximum horizontal deflection for both time bases).

The sweep speed of each time base may be further extended with the use of the MAGNIFIER control. When turned on, the 5X magnification magnifies the center 2-centimeter portion of the oscilloscope display. Using this control increases the sweep rate of Time Base A to 0.02 microsecond per centimeter and increases Time Base B sweep rate to 0.4 microsecond per centimeter.

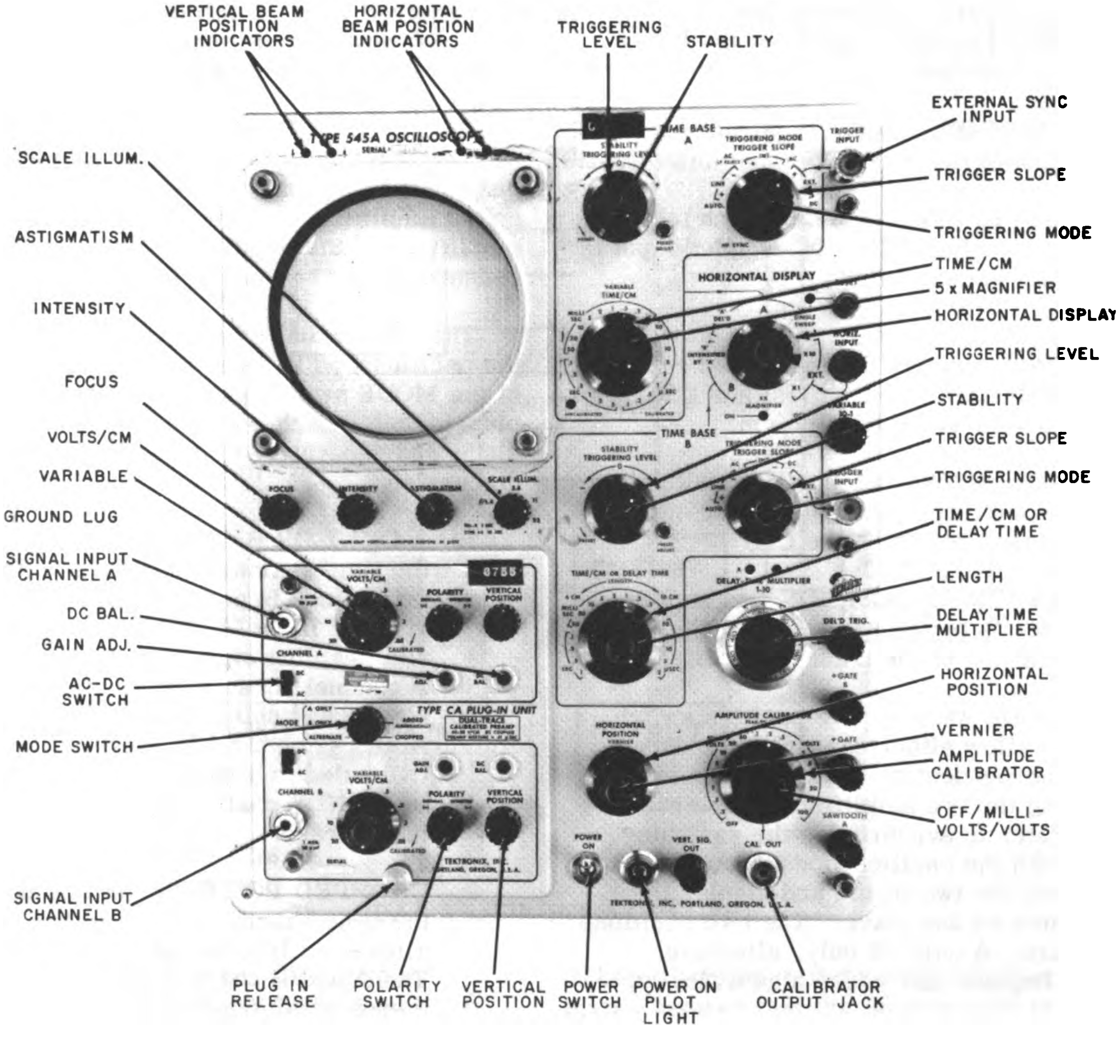
To initiate the horizontal display for Time Bases A or B, a trigger is used that may be derived from one of three sources; EXT., INT., or LINE. The source used is selected by the TRIGGER SLOPE switch; this control also selects the slope (positive or negative) of the triggering signal that is used to initiate the sweep.

Used in conjunction with the TRIGGER SLOPE control is the TRIGGERING MODE control. Time Base A has five triggering modes; AUTO, AC, DC, LOW FREQUENCY

REJECT and HIGH FREQUENCY SYNC, while Time Base B has three; AUTO; AC and DC. Each of the triggering modes is designed to provide stable triggering from a certain type waveform. The mode used is a matter of choice and is selected on the basis of whether or not it allows you to obtain the desired display.

VERTICAL DEFLECTION

The vertical display for the CRT is derived from a plug-in pre-amp unit. There are a number of pre-amps available for use with the 545A Oscilloscope; however, in this text we are only concerned with those most commonly used in the maintenance of fire



71. OSCILLOSCOPE, TEKTRONIX 545A

control equipment. Therefore, we will limit our discussion to the type 53/54C plug-in pre-amp.

The type 53/54C plug-in unit is a dual trace preamplifier that consists of two identical amplifier channels (A and B). Each channel has its own positioning and attenuation controls that operate independently of the other channel. The controls of interest mounted on the front panel are marked as follows:

1. CHANNEL A (OR B): signal input jack to the A or B channel amplifiers.
2. DC-AC switch: slide switch to provide either AC or DC coupled input into the amplifier.
3. VOLTS/CM: nine position switch used to select the calibrated vertical-deflection sensitivities; has a range of 0.05 V/cm to 20 V/cm.
4. POLARITY: two position switch to provide optional in-phase or out-of-phase display on the CRT.
5. VERTICAL POSITION: potentiometer to provide for shifting the position of the trace vertically.
6. MODE switch: five position switch to allow either channel to be used independently, to provide for switching the two amplifiers at an arbitrary rate, to synchronize the switching with the oscilloscope sweep, or to add the two inputs and display the sum as one trace. The five positions are: A only, B only, alternate, chopped, and added algebraically.

The remaining controls on the front panel are screwdriver adjustments used when aligning the scope itself and should not be adjusted.

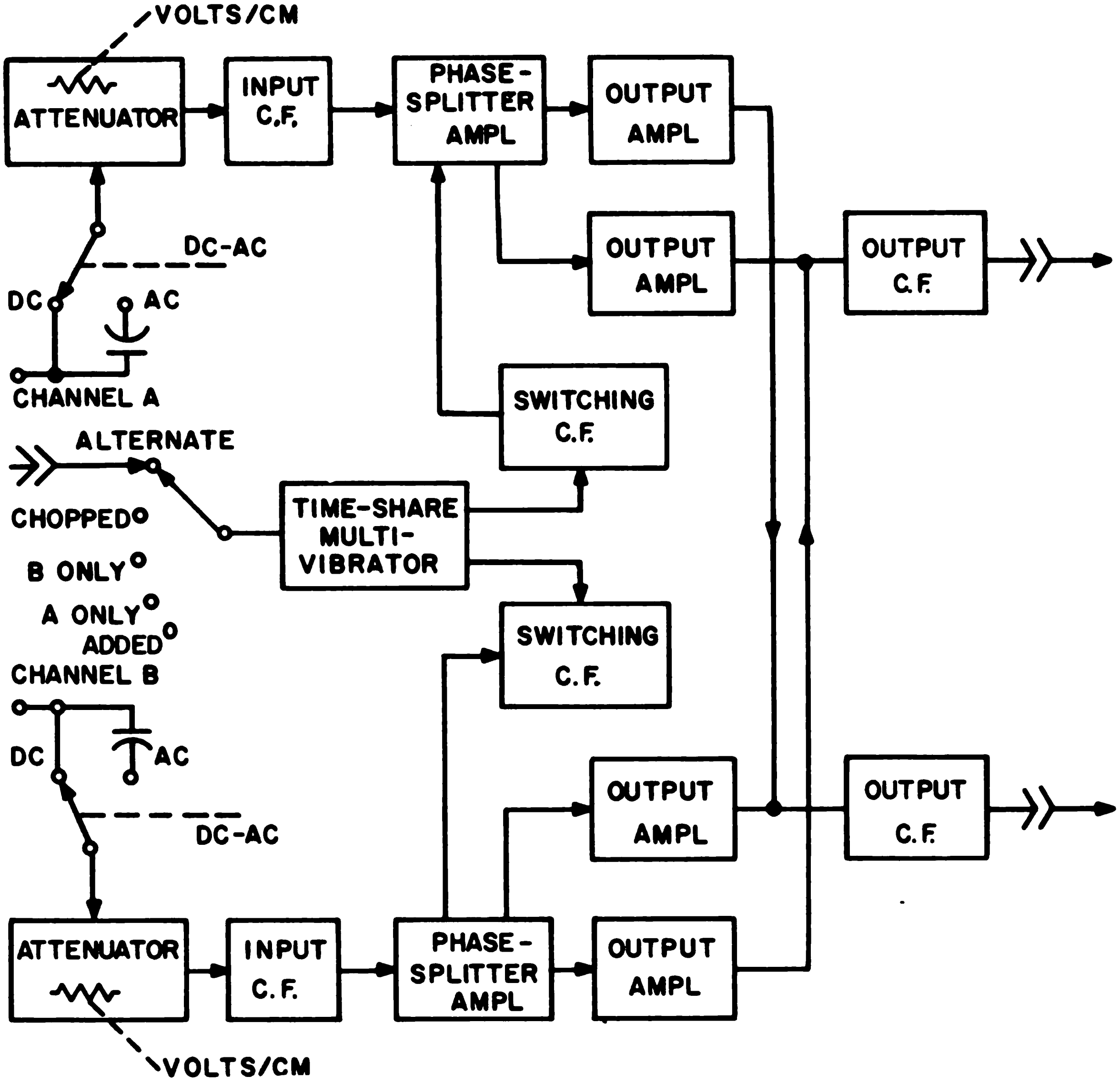
Since the dual amplifier channels are identical only the operation of one channel will be described. (Refer to the drawing of the Dual Trace Preamplifier.) The input video signal is applied to the attenuator control via the DC-AC switch. When in the AC position, a DC blocking capacitor is placed into the input circuit and the DC level of the input signal is blocked. Hence only the AC signal will be passed and no DC level can be measured. In the DC position the blocking capacitor is bypassed and the DC level is applied to the attenuator control.

The amount of attenuation is controlled by the VOLTS/CM switch and is set to give the required vertical deflection on the CRT. The attenuated output is applied to a phase splitter amplifier via an input cathode follower.

The phase splitter amplifier provides a push-pull output that is amplified by the output amplifiers and applied to the vertical amplifiers of the oscilloscope via the impedance matching cathode followers.

The type of display that is presented on the oscilloscope is determined by the setting of the MODE switch on the front panel of the plug-in unit. Each position of this switch is discussed separately in the following discussion.

1. A ONLY OR B ONLY: in this position the time sharing multivibrator is maintained in one of its two stable states. In the A ONLY position a 0 volt enabling signal is applied to the A channel phase splitter amplifier via the switching cathode follower. At the same time, a disabling positive pulse is applied to channel B. In B ONLY position the above action is reversed.
2. CHOPPED POSITION: in this position, the time sharing multivibrator is allowed to free run at a 100 kc rate. The A and B channel amplifiers are therefore alternately turned on and off at this rate.
3. ALTERNATE: in this position the time sharing multivibrator is converted to a bi-stable multivibrator (BSMV). At the end of each sweep on the oscilloscope display, a trigger is generated in the main sweep circuit of the oscilloscope and coupled to the time sharing multivibrator. The multivibrator alternately changes state at a rate determined by the



72. DUAL TRACE PREAMPLIFIER

sweep speed of the CRT display thereby alternately turning on the A and B channel amplifiers at this same rate.

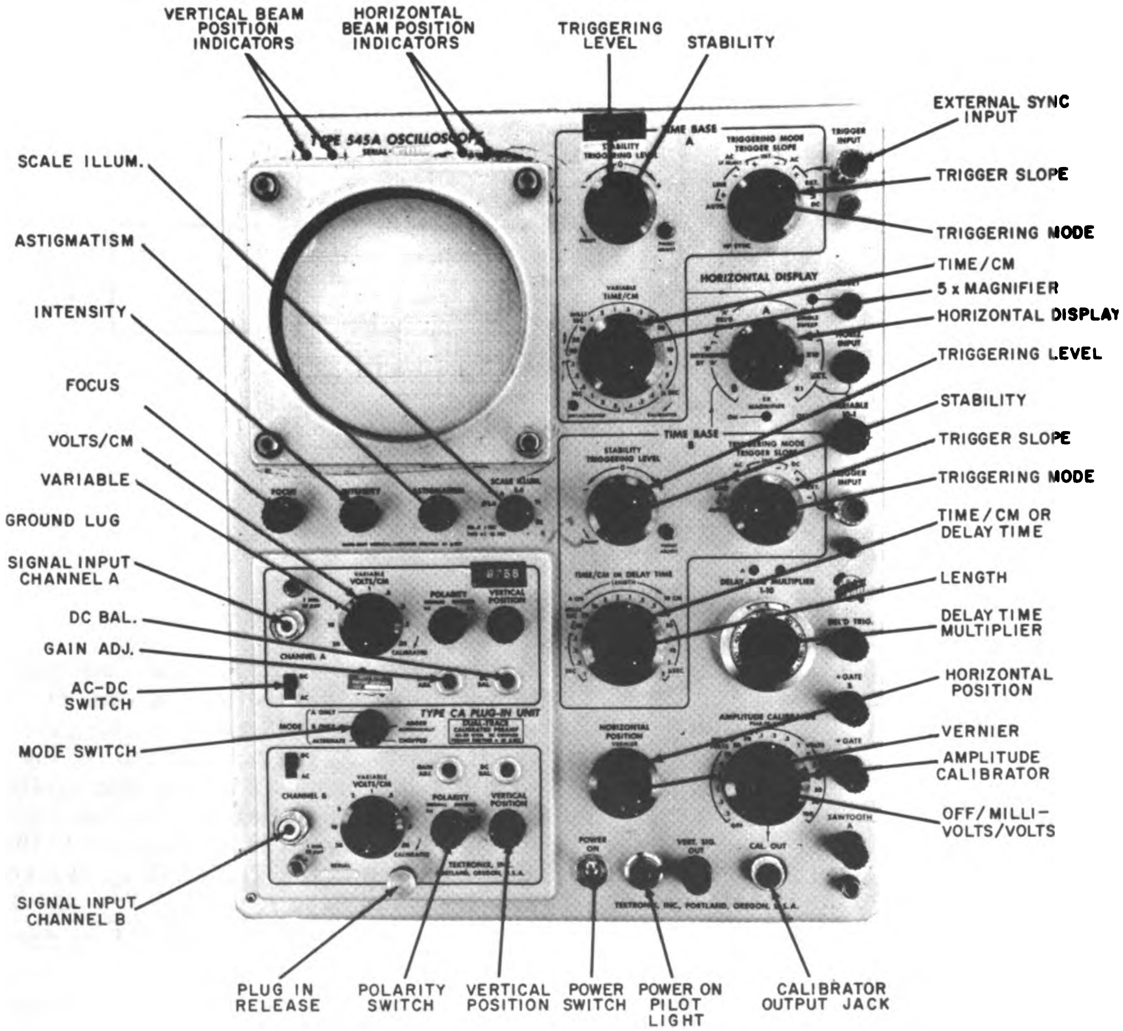
The signal from the plug-in pre-amps is applied to the input vertical amplifier of the oscilloscope in push-pull. After being amplified it is applied to the 0.2 micro-second delay line via the grid line driver amplifiers. The delay of the signal prior to being applied to the vertical deflection plates insures that the leading edge of the signals will be displayed when using internal triggering. The output signal of the grid line driver amplifiers is also applied to the trigger amplifier and cathode follower circuit. The signal is then applied to the INT. position of the TRIGGER SLOPE control for Time Base A and B. The output signal is also available at the VERT SIG OUT jack.

TIME BASE GENERATION

The HORIZONTAL DISPLAY switch in the illustration is in the Time Base B position. Therefore that time base will be discussed here. Time Base A is similar.

From the INT. position of the TRIGGERING SLOPE control the signal is amplified by the trigger input amplifier and is applied to the trigger multivibrator. The TRIGGERING MODE control determines the circuit parameters of the trigger input amplifier, while the TRIGGERING LEVEL control determines the bias of the amplifier. Upon receipt of the trigger, the trigger multivibrator produces a square wave output. This output is differentiated and the resulting negative trigger is used to flip the sweep gating BSMV. The output of the BSMV will gate on a Miller run-up circuit, which will generate a sawtooth voltage. The width of this sawtooth waveform (or sweep speed) is controlled by the TIME/CM control.

To prevent the sweep gating BSMV from being flipped by every input trigger and thereby ending the sawtooth waveform, a hold-off circuit is used. This circuit receives the sawtooth output of the Miller run-up circuit and applies it to the input circuit of the sweep gating multivibrator as a bias voltage. At the time that the sawtooth waveform reaches its predescribed value, thereby providing full scale deflection on the face of the CRT, the bias on the sweep gating multivibrator



73. OSCILLOSCOPE, TEKTRONIX 545A

will be lowered sufficiently to allow the next input trigger to flip it. When the BSMV flips, the circuit is returned to its static state, and upon receipt of the next input trigger the circuit will be activated again.

The TIME/CM control determines the sweep speed (duration of the sawtooth output) by selecting various RC networks in the plate and grid circuits of the Miller run-up-circuit. These RC networks vary the amount of time necessary for the sawtooth output from the Miller run-up circuit to reach a value of voltage sufficient to provide 10 cm of horizontal deflection on the CRT.

The SWEEP LENGTH control of only Time Base B can be varied by the SWEEP LENGTH control from 4 to 10 cm. This control varies the level of bias voltage applied to the sweep gating BSMV thereby determining which input trigger will initiate it. This action results in the sawtooth output ending before it has reached a value of voltage sufficient to deflect the CRT electron beam the full 10 cm.

The output of the Miller run-up circuit is applied to the horizontal amplifier via section 2R and 1F and R of the HORIZONTAL DISPLAY switch. The horizontal amplifier amplifies the sawtooth voltage and applies it to the horizontal deflection plates of the CRT. The HORIZONTAL POSITION control varies the position of the display by changing the DC level to which the sawtooth waveform is clamped. The 5X MAGNIFIER control essentially does the same thing; however it also increases the magnitude of the sawtooth output voltage. The result is that the center 2 cm display is expanded to cover the full 10 cm's.

The sweep gating multivibrator for Time Base B has two outputs in addition to the one applied to the Miller run-up circuit. One output is applied to the +gate output cathode follower where it is applied to an external jack; and also to the unblank cathode follower. From here it is applied to the CRT circuits via section 3R of the HORIZONTAL DISPLAY switch. This pulse will be applied to the grid of the CRT and will turn the beam on, thereby allowing a presentation.

The other output of the sweep gating BSMV is sent to the alternate trace sync amplifier via section 4R of the HORIZONTAL DISPLAY switch. The pulse is differentiated here and the resulting trigger is used to trigger the time sharing multivibrator in the plug-in and pre-amp when the MODE control is in the ALTERNATE position.

The Time Base B Miller run-up circuit output is also applied to a difference amplifier circuit via section 2F of the HORIZONTAL DISPLAY switch. This circuit is essentially a comparison circuit that will generate a trigger when the sawtooth voltage level equals the voltage level controlled by the DELAY TIME MULTIPLIER control. As this control is variable the level at which coincidence occurs can be varied, thereby varying the output trigger in time. This trigger is applied to the delayed trigger MSMV to initiate the generation of a square wave. The square wave is differentiated and the resulting negative trigger is applied to the 1F section of the HORIZONTAL DISPLAY switch. The output trigger is also applied to the DEL'D TRIG. jack where it is available for external use.

When the HORIZONTAL DISPLAY switch is in the Time Base A position, circuit operation is similar to that described for Time Base B except that Time Base A circuits are used.

In the B INTENSIFIED BY A position of the HORIZONTAL DISPLAY switch, the following action takes place. (During the following discussion it is assumed that the Time Base A TIME/CM control is set at a faster sweep than the Time Base B control.) The circuit operation for Time Base B is identical as that previously discussed. The exception is that the delayed trigger from the delayed trigger MSMV is applied to the delayed trigger amplifier via section 1F of the HORIZONTAL DISPLAY switch. Also during this mode the lock-out multivibrator is functioning and prior to receiving a delayed trigger is holding the sweep gating BSMV for Time Base A in the off position. Upon receipt of the delayed trigger, the lock-out multivibrator flips and allows the Time Base A sweep gating BSMV to also flip. The width of the output pulse at this time depends upon the setting of the Time Base A TIME/CM control. The output square wave is then applied to section 3R of the HORIZONTAL DISPLAY switch via the unblank cathode follower. From here this unblank pulse is added to the unblank pulse from Time Base B and will be applied to the CRT circuits. When the sum of these two output pulses is applied to the CRT grid it will result in the Time Base B sweep (which covers the entire 10 cm face of the CRT) being intensified by the Time Base A unblank pulse. The width of the intensification is determined by the Time Base A TIME/CM control while the position will be determined by the DELAY TIME MULTIPLIER control. By varying the latter control the intensification can be positioned to any place on the sweep.

After setting the intensified portion to the position desired, the HORIZONTAL DISPLAY switch may be positioned to the A DELAYED BY B position. The intensified portion of the preceding position of the switch will now cover the entire 10 cm of the CRT. This is accomplished by removing the sawtooth sweep voltage from Time Base B to the horizontal amplifier and substituting the sawtooth voltage from Time Base A. In this position the sweep presentation may be moved in time by turning the DELAY TIME MULTIPLIER control.

This scope may also be used to present a Lissajous pattern. To accomplish this, the HORIZONTAL DISPLAY switch is placed into the EXT. position (either the X10 or X1 position may be used). This removes the sawtooth sweep from the horizontal amplifier and substitutes a signal from the HORIZONTAL INPUT external jack. By applying a signal to this jack that is 90 degrees out of phase with that applied to the plug-in pre-amp, a circle may be obtained on the face of the CRT. The amplitude of the input signal from the HORIZONTAL INPUT jack can be varied prior to being applied to the horizontal amplifier by varying the 10:1 ATTENUATOR control.

The positions of the HORIZONTAL DISPLAY switch that have been discussed in the previous paragraphs are those that are most commonly used by the fire control technician. The remaining positions are seldom used, and therefore are not discussed in this text.

PULSE ANALYSIS

To properly use the Oscilloscope, Tektronix 545A, it is imperative that the trainee have a knowledge of time base diagrams, and the associated definitions. The oscilloscope display is a time base diagram which displays a plot of voltage versus time. Voltage is displayed on the vertical axis, or ordinate, and the horizontal axis, or abcissa represents time. The dimension of the quantity time, is usually in μ sec. Although it may be expressed in millisecond, seconds, or minutes.

To determine if a circuit is operating properly, circuit waveshapes may be displayed on an oscilloscope. From the oscilloscope display it is possible to obtain a set of measurements which yields the desired information. When viewing a square wave the measurements that can be made are:

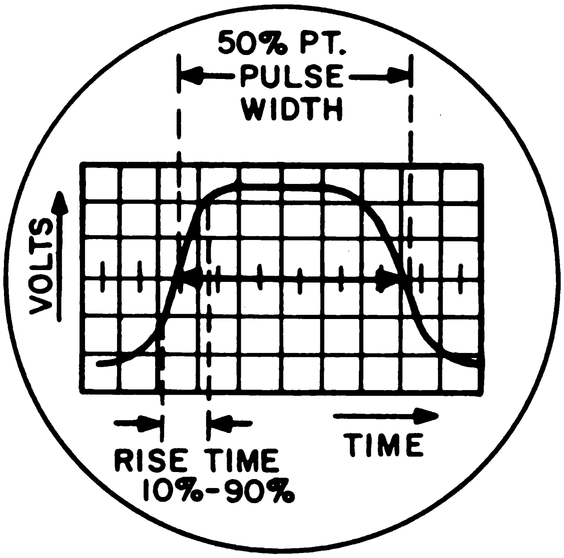
1. Rise time
2. Pulse width
3. Fall time or decay time
4. Pulse jitter

Rise time is usually defined as the time it takes for the voltage to rise from the 10% point to the 90% point of the leading edge of the wave. In some cases, the rise time will be taken from the 1 db point to the 6 db point. The faster the rise time, the shorter the amount of time it takes the voltage to rise from the 10% to 90% points. Rise time of a pulse is given in μ sec.

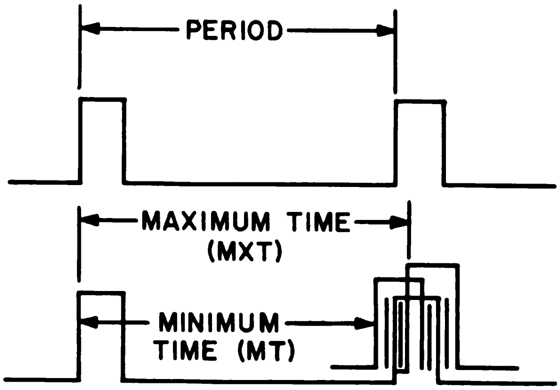
The pulse width is usually measured from the 50% point of the leading edge to the trailing edge of the square wave. Pulse width is given in μ sec. The wider the pulse width, the longer the time duration of the pulse.

The decay time is usually defined as the time it takes the voltage to fall from the 80% to the 10% points of the square wave trailing edge. Decay time is given in μ sec. The smaller the decay time, the steeper the slope of the trailing edge.

The time interval between two given pulses is defined as the pulse interval or period.

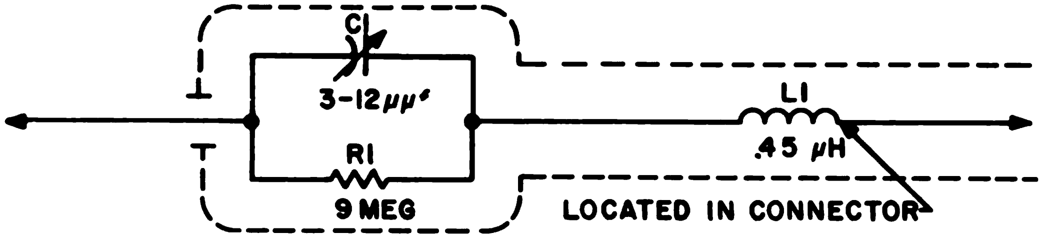


74. TIME BASE DIAGRAM



75. PULSE JITTER MEASUREMENT

The amount the pulses vary in time with respect to each other, is called pulse jitter. Pulse jitter may be due to a variety of causes. But if the jitter is excessive it may have serious effects on the reliability of a radar.



76. LOW CAPACITANCE PROBE, TYPE P6000, SCHEMATIC DIAGRAM

Experiment 3-5-1, Probe Adjustment

In this experiment you will learn to adjust the Tektronix Low Capacitance Probe, Type P6000, illustrated above. You will see the effect or probe adjustment on the scope calibrator output waveforms.

An adjustable capacitor in the probe body, below, compensates for variations in input capacitance from one instrument to another. To insure the accuracy of pulse and transient measurements, this adjustment should be checked frequently.

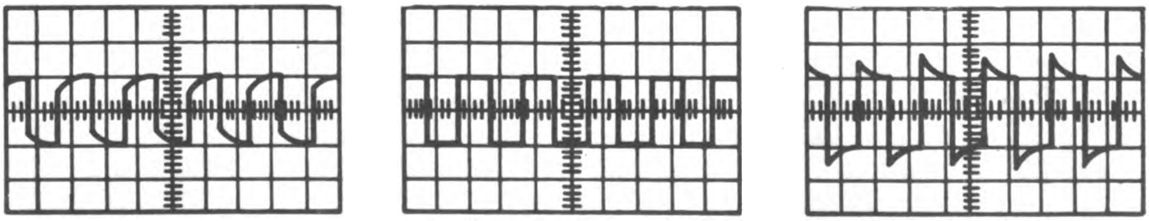
To adjust the P6000 probe, set the Calibrator control for a calibrator output signal of suitable amplitude. Touch the probe tip to the CAL. OUT connector and adjust the oscilloscope controls to display several cycles of the waveform. Unlock the probe for adjustment by turning the locking sleeve at the rear of the probe body 4 or 5 turns counterclockwise. Hold the probe firmly by the notched flange at the base of the probe, and adjust by turning the probe barrel for an optimum waveshape as shown in the center waveform illustration below.

After a good flat-top square wave is achieved, turn the locking ring clockwise until it is fairly tight but not too tight. Holding the probe by the barrel, make fine adjustments by turning the notched flange. Carefully tighten the locking ring.

REVIEW AND SUMMARY

In this topic you have studied the Oscilloscope, Tektronix 545A. The main points you should have learned include:

1. The capabilities and special features of the Oscilloscope, Tektronix 545A.
2. The names, function and use of the various front panel controls.
3. Description, signal flow and modes of operation of the dual trace plug-in amplifier.
4. Description, signal flow and modes of operation of the 545A Oscilloscope.
5. Construction, adjustment and use of the P6000 low capacitance probe.
6. Measurement of rise time, pulse width, decay time and pulse jitter.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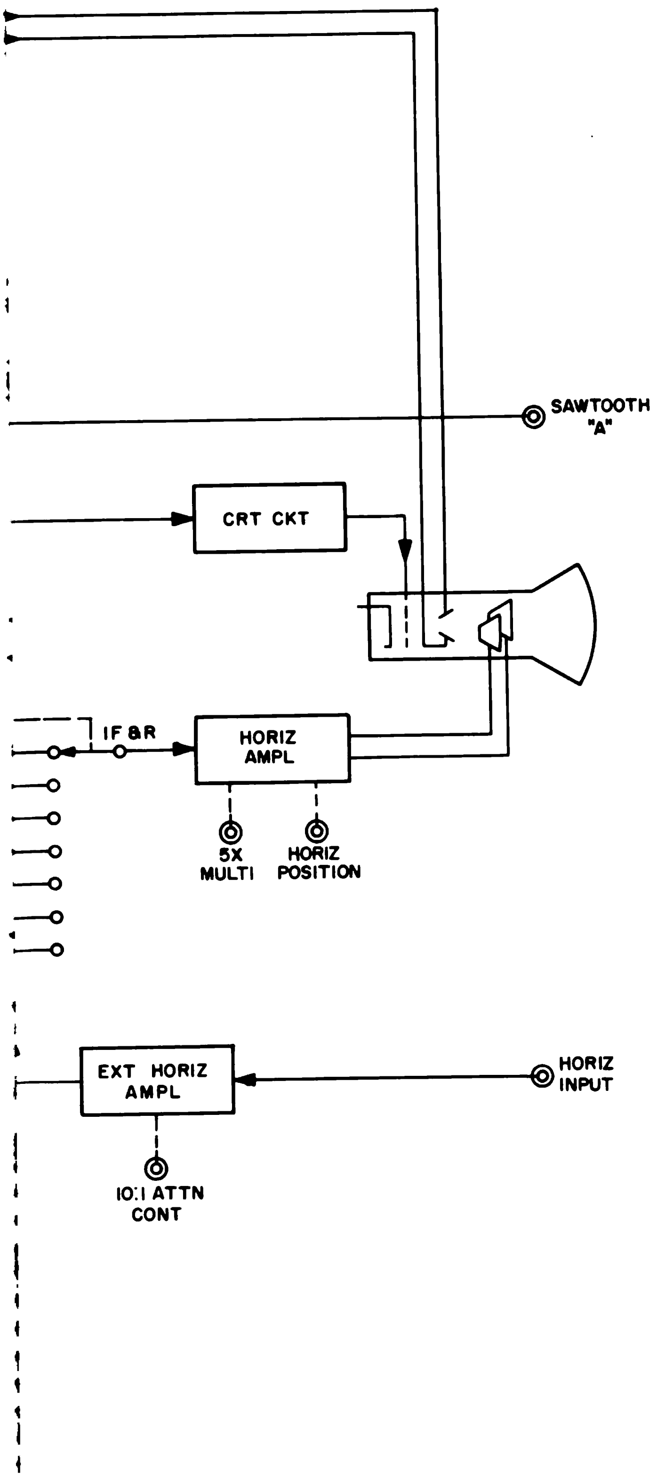
77. PROBE ADJUSTMENT WAVEFORMS



78. OSCILLOSCOPE 545A, BLOCK DIAGRAM

QUIZ SHEETS:

Answer the following questions. If necessary refer to the OP, the OD, or to the equipment.

1. What are the two basic types of cathode ray tubes?

2. What happens to electrons after they strike the screen of a cathode ray tube?

3. Does the electron beam paint a backward picture during retrace time? Why?

4. What is the purpose of the sweep generator section of an oscilloscope?

5. What is the purpose of a low capacitance probe?

6. Is the same amplitude of input signal available at the scope when using a low capacitance probe as compared to a direct probe? Why?

7. What should be done to a low capacitance probe before using it with a scope? How?

8. What are the ways of measuring frequency with a scope?

9. Describe briefly what Lissajous patterns are and how to use them.

10. Describe some methods of making phase relation comparisons with an oscilloscope.

11. What is the primary difference between a synchroscope and a general purpose oscilloscope?

12. Describe how to measure voltage amplitude with any oscilloscope.

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CODE OF CONDUCT

FOR MEMBERS OF THE ARMED FORCES OF THE UNITED STATES

THE CODE

I

I am an American fighting man. I serve in the forces which guard my country and our way of life. I am prepared to give my life in their defense.

II

I will never surrender of my own free will. If in command I will never surrender my men while they still have the means to resist.

III

If I am captured I will continue to resist by all means available. I will make every effort to escape and aid others to escape. I will accept neither parole nor special favors from the enemy.

IV

If I become prisoner of war, I will keep faith with my fellow prisoners. I will give no information nor take part in any action which might be harmful to my comrades. If I am senior, I will take command. If not, I will obey the lawful orders of those appointed over me and will back them up in every way.

V

When questioned, should I become a prisoner of war, I am bound to give only name, rank, service number, and date of birth. I will evade answering further questions to the utmost of my ability. I will make no oral or written statements disloyal to my country and its allies or harmful to their cause.

VI

I will never forget that I am an American fighting man, responsible for my actions, and dedicated to the principles which made my country free. I will trust in my God and in the United States of America.

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